DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the Office of NOAA Corps Operations (NC).

NATIONAL WEATHER SERVICE

The National Weather Service (NWS) has the principal responsibility for the plans and operations of the basic weather services and certain specific applied services. The primary mission of NWS is to help ensure the safety and welfare of the general public with respect to the effects of weather and to further the conduct of governmental and commercial activities which are affected by weather. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood, and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the United States and its possessions.
- Develops and operates national meteorological, hydrological, and oceanic service systems.
- Performs applied meteorological and hydrological research.
- Assists in developing community awareness and educational materials concerning weather-related natural disasters.
- Participates in international hydrometeorological activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for provision of weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).

SERVICES

NWS provides around-the-clock weather and flood warning and forecast services to the public for the protection of life and property and to meet the needs of all segments of the economy. Weather services are provided primarily by a restructured national network of 121 Weather Forecast Offices (WFOs) and 13 River Forecast Centers (RFCs) assisted by 13 Data Collection Offices (DCOs) who collect data, prepare state and local warnings and forecasts, and disseminate information to the population both directly and indirectly through the mass media. (Figure 3-DOC-1 shows the location of WFOs and RFCs) Data, analyses, forecasts, and outlooks used by field forecasters to prepare local forecasts are centrally processed by the National Centers for Environmental Prediction (NCEP). The NWS core mission also depends on the study, development, and testing of new methods for improving basic warning and forecast capabilities through research.

Weather Warnings and Forecasts. At 121 WFOs, nationwide, NWS forecasters issue local warnings of severe weather such as tornadoes, severe thunderstorms, flash floods, and extreme winter weather.

WFOs prepare forecasts for zones which are comprised of several counties that experience similar weather. Each WFO has forecast responsibility

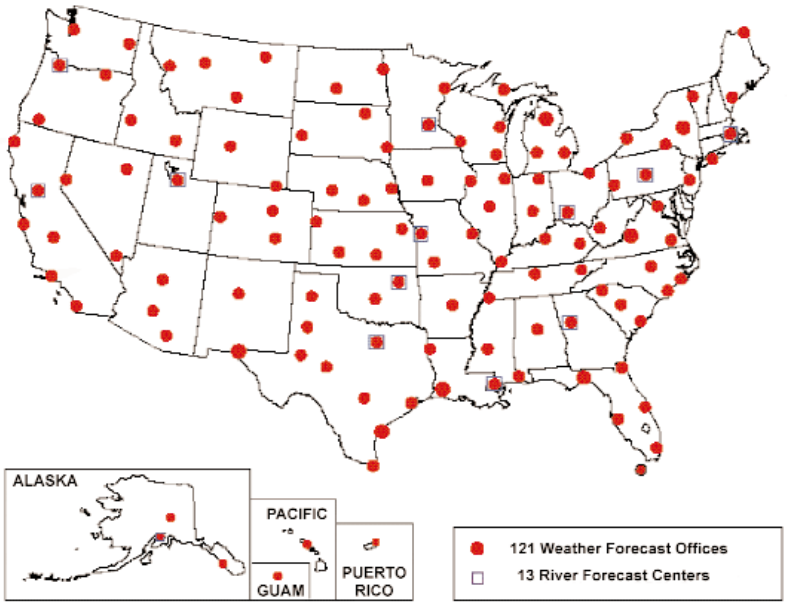

Figure 3-DOC-1. National Weather Service Office Locations

for several zones. WFOs also provide the main field forecast support for the marine and aviation programs as well as guidance for the fire weather program supporting federal lands management and wildfire control.

All counties in the United States are assigned to specific WFOs for warning purposes. These offices issue and distribute local warnings of severe weather for their assigned counties. WFOs adapt generalized weather forecasts to local areas and issue severe weather and flash flood warnings.

In preparing local warnings and forecasts, WFOs use value-added forecast guidance prepared by NCEP. Functions of the National Centers also provide central support for the local warning program.

Aviation Weather Services. The NWS provides a broad range of services in support of the aviation community. WFOs prepare site specific airport terminal forecasts four times per day with amendments as needed for over 500 public-use airports in the 50 states and in the Caribbean. These offices also produce about 300 individual route-oriented forecasts three times per day for the 48 contiguous states. (Figure 3-DOC-2 is an example of an AWIPS display used by forecasters to prepare aviation products).

NCEP's Aviation Weather Center prepares Area Forecasts 3 times daily describing general aviation weather conditions over the lower 48 states. This unit also issues in-flight advisories of hazardous weather conditions associated with thunderstorms, icing, turbulence, strong low-level winds, and broad areas of low clouds and/or restricted visibility. In Alaska and Hawaii, these products are issued by WFOs. In Alaska, the Alaska Aviation Weather Unit issues aviation products specifically for that state.

Marine Weather Services. Using weather analysis and forecast guidance provided by NCEP, marine weather forecasters at coastal and Great Lakes WFOs issue wind, wave, weather, and ice warnings, forecasts, and other information for the population living and working along the sea coast, off-shore, on the Great Lakes, and the high seas. Principal products include small craft advisories, gale, storm, tropical cyclone, and storm surge warnings; coastal, off-shore, and high seas forecasts; sea and swell forecasts; sea and lake advisories; and special weather forecasts to aid in the containment and clean up of oil spills and other hazardous substances in the marine environment.

Fire Weather Services. Many WFOs in the Western and Southern parts of the country are staffed to provide wildfire suppression support, and support to prescribed burns on federal lands.

Tsunami Warnings. Tsunami watches and warnings for Pacific Ocean areas and Alaska are prepared and issued by the Tsunami Warning Center at Ewa Beach, Hawaii, and the regional center at Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories and sea-level observing stations which operate on a cooperative basis. The centers use the data to prepare watches and warnings covering all United States territories and states bordering on the Pacific Ocean and disseminate them to WFOs, federal and state disaster agencies, military organizations, private broadcast media, and other facilities that can furnish warning information to the public.

National Centers for Environmental Prediction

Over the last several decades, NWS has made major improvements in forecasting synoptic-scale (large-scale, slowly evolving) weather. As modernization efforts continue, further improvements will be realized in the severe weather and flood warnings program with continuing improvements in larger scale, centrally prepared weather guidance products for Day II and beyond, implementation of NWS systems upgrades, advanced observations from the planned geostationary and polar-orbiting satellites, and the development of mesoscale predictive techniques for NWS field operations. Integral to the modernization effort, NWS is reorganizing its field structure to focus more on warnings and short-range forecasts, and, in FY 1995, National Meteorological Center (NMC) was restructured to serve a broader mission required by the NWS modernization. The modernized operations concept includes a vertically integrated forecast process in which national centers provide products

based on output from numerical models, statistical adjustments to model fields, and value-added products prepared by national center forecasts. This product suite will be transmitted to the modernized Weather Forecast Offices (WFO) in digital form, where forecasters will use them to prepare local forecast products. Under the new, modernized office structure, the responsibilities of the Weather Service Forecast Offices (WSFOs) and the Weather Service Offices (WSOs) will be subsumed by the WFOs.

Improved technologies allowed NOAA to reorganize the NMC into NCEP with nine science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models on which predictions are based. NCEP provides an integrated suite of forecast guidance and specific forecast products from the short-term through seasonal, interannual, decadal, and centennial time frames. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value-added forecast guidance products for NWS field offices and direct users.

Storm Prediction Center. The Storm Prediction Center (SPC) focuses on hazardous weather events such as severe thunderstorms and tornadoes, ice or heavy snow, and flash floods, with emphasis on the first few hours of the forecast period. Products issued from the SPC give the WFOs specific guidance as to the probability and intensity of severe weather occurrences for regional to local geographic scales.

Hydrometeorological Prediction Center. The Hydrometeorological Prediction Center (HPC) has the responsibility for preparing quantitative precipitation forecasts (QPF) that are used by WFOs to develop local rainfall, snow, and ice forecasts and by the RFCs to develop local river and flood forecasts. The HPC provides special QPFs and coordination to other federal agencies such as the Federal Emergency Management Agency (FEMA) during major flood events. The HPC also provides an array of analyses and forecasts of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community.

Marine Prediction Center. The Marine Prediction Center (MPC) discharges United States international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS) to which the United States is a signatory. It provides one-stop-shopping for marine interests operating outside the domain of coastal WFOs. The HPC provides weather and sea state warnings and forecasts for the high seas of the Northern Hemisphere for planning and operational purposes. Its

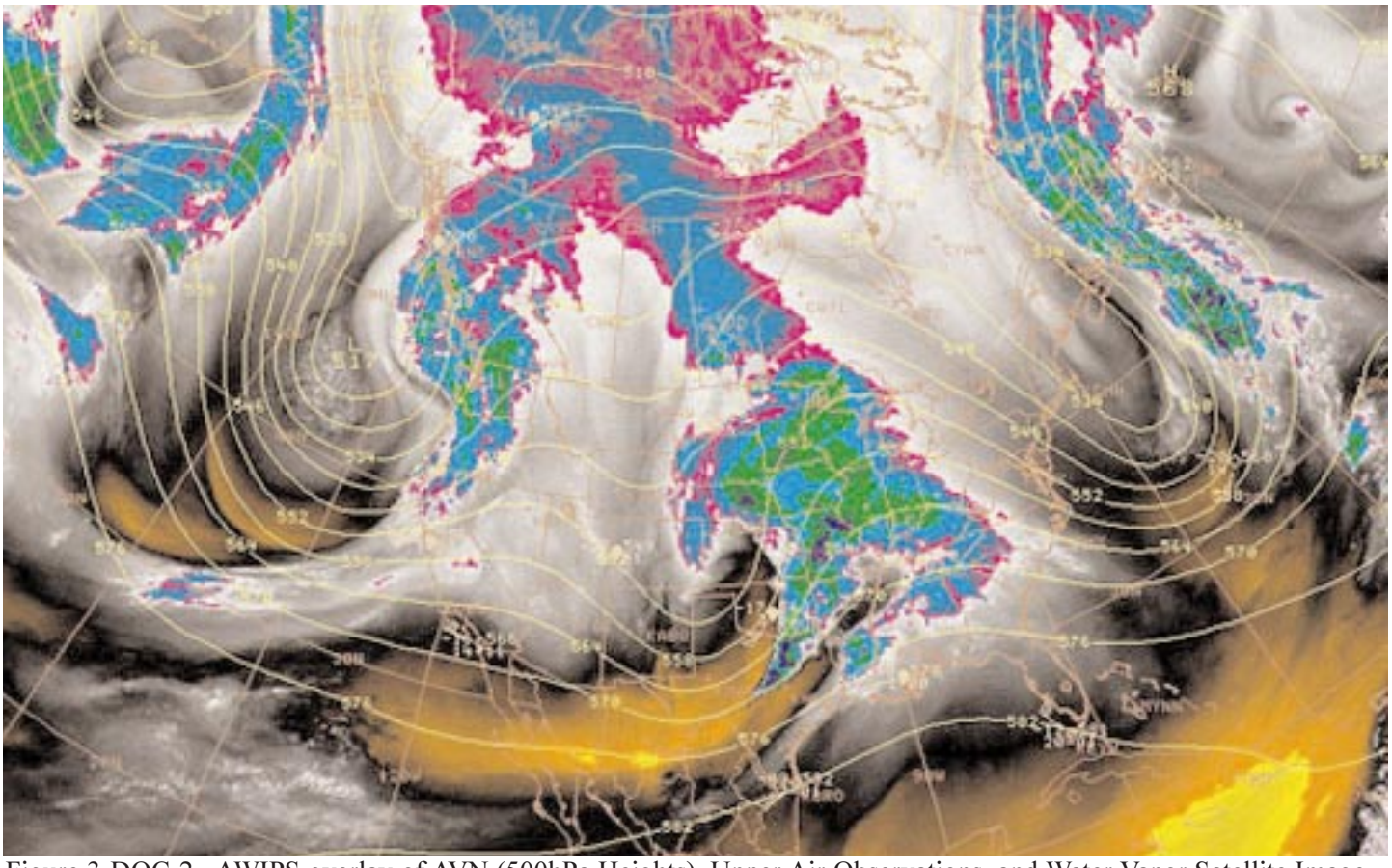

Figure 3-DOC-2. AWIPS overlay of AVN (500hPa Heights), Upper Air Observations, and Water Vapor Satellite Image.

warnings and products go directly to ships at sea and are vital for the protection of life and property.

The MPC also provides guidance forecasts for WFOs with coastal responsibilities, which extend out to about 100 nautical miles. Coastal WFOs have responsibility for local forecasts and warnings out to that limit; for the high seas beyond, the responsibility has been centralized in the HPC.

Tropical Prediction Center/National Hurricane Center. The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC) in Miami, Florida. Services provided by the TPC/NHC include advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific Oceans, the Caribbean Sea, and the Gulf of Mexico, including the portions of the coastline threatened by such storms.

In addition, TPC forecasters provide aviation and marine analyses and forecast products for the same areas of responsibility. The TPC/NHC functions both to provide guidance, coordination, and tropical weather expertise to WFO forecasters and to serve users of centrally-generated products.

Aviation Weather Center. The Aviation Weather Center (AWC) is the mechanism by which the United States discharges its weather forecasting obligations to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, temperature, and flight hazard (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for the United States, the north Atlantic and north Pacific routes, and some routes in the Southern Hemisphere.

In addition to the enroute weather support provided for the aviation industry, the AWC also produces guidance products for use by WFOs in support of the airport terminal forecast function. Thus, the AWC discharges large-scale, global aviation functions which can be sensibly centralized, while the WFOs discharge local aviation functions based on centralized guidance provided by the AWC.

Climate Prediction Center. The Climate Prediction Center (CPC) produces climate services consisting of operational prediction of climate variability, monitoring of the climate system and development of data bases for determining current climate anomalies and trends, and analysis and assessment of their origins and linkages to the rest of the climate system. These services cover climate time scales ranging from weeks to seasons, extending into the future as far as technically feasible, and cover the domain of land, ocean, and atmosphere extending into the stratosphere. CPC climate services are used by WFOs as well as the public, private industry, and the international research community.

Space Environment Center. The Space Environment Center (SEC), located in Boulder, Colorado, provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues specific predictions of the activity level of space weather for the next 3 days and more general predictions up to several weeks in advance. Weekly summaries of observed solar-terrestrial conditions are also published. The SEC supports theoretical and experimental research to understand the fundamental physical processes governing the space environment and the development of operational techniques and processes. Research activities focus on areas where advanced applications can be developed to help improve the Nation's space weather service.

Environmental Modeling Center. The Environmental Modeling Center (EMC) located in Camp Springs, Maryland, improves NCEP's numerical weather, marine, and climatic predictions through a broad program of data assimilation and computer modeling. In support of the NCEP operational mission to provide ocean prediction, mesoscale prediction (thunderstorms, hurricanes, tornadoes, etc.), and global prediction, EMC develops, adapts, improves, and monitors data assimilation systems and models of the atmosphere, ocean, and atmosphere/ocean system using advanced modeling methods developed internally, as well as cooperatively with scientists from universities, the international scientific community, NOAA laboratories, and other government agencies. The EMC integrates research and technology through its Model Test Facility (MTF). The MTF serves as an efficient and effective interface between NCEP and the scientific community which may develop ideas, models, and techniques that will improve NCEP products. The MTF provides consultation, programming, and computer resources to outside scientists using the NCEP system and coordinates initial evaluations of their work. The EMC conducts applied research and development and publishes research results in various media for dissemination to the world meteorological and oceanographic community.

NCEP Central Operations. The NCEP Central Operations (NCO) located in Camp Springs, Maryland, is responsible for all aspects of NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems. The NCO provides management, procurement, development, installation, maintenance, and opera-

tion of all computing and communications-related services which link the individual NCEP activities together. The NCO is the focal point for the establishment and execution of policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO houses and runs the super-computer facility and implements and monitors the management of all operational modifications to NCEP products to ensure the reliability of scheduled services. The NCO provides the technical transition between the research and development of numerical weather and climate prediction models and their operational use. The NCO also manages the NCEP databases for use by numerical weather and climate prediction systems and other operational and developmental efforts of NCEP. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS mainframe and supercomputer systems, workstations, graphics plotters, and personal computers.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather and flood warning and forecast services to the public.

Meteorological Research. The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques used in weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms). These techniques will be developed and improved to use digital data from new observing systems such as the Next Generation Weather Radar (NEXRAD) with Doppler capability (Figure 3-DOC-3) and geostationary satellites with higher resolution (GOES-NEXT).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.

Hydrological Research. The NWS develops improved hydrologic and hydrometeorological models and procedures in support of the national flood forecasting and water resources forecasting programs including:

- Improvements to the Extended Streamflow Prediction model and its complementary models in the NWS River Forecast System.

Figure 3-DOC-3. Next Generation Weather Radar (WSR-88D).

- Specialized flood and flash flood forecasting procedures using linked hydrological and meteorological models.
- Algorithms to combine WSR-88D precipitation estimates with data from satellites and other ground-based observation systems.

MODERNIZATION

A Strategic Plan for the Modernization and Associated Restructuring of the NWS was submitted to Congress in 1989. Implementation of the plan will optimize efficiency and effectiveness of the mesoscale warning and forecast program and will include an operational demonstration and evaluation program as required by Public Law 102–567 to refine operational procedures and resolve implementation issues best addressed through actual field experience. Continued improvements in larger scale, centrally prepared weather guidance products for Day II and beyond through advanced forecasting models and the requested increased computer processing capability are essential to successful implementation of mesoscale forecasting in NWS field operations, where field forecasters will concentrate on the small-scale, short-lived processes that occur in the 0 to 36-hour timescale.

The National Implementation Plan provides a planning framework and general strategies for accomplishing the transition as well as advanced notification of when implementation activities are scheduled to occur at each site. The interrelationships of all of the activities--facilities preparation, staffing augmentation, training, commissioning of systems, and realigning operations and services--have begun so that the demonstration can begin in 1996. In addition to preparations for the demonstration, nationwide planning and implementation have begun. Facilities construction is ongoing; training for field personnel is being conducted with necessary backup personnel to cover operational shifts; software development continues; new communications are being established; and all NWS offices have developed

and are updating detailed site plans for the transition. The NWS modernization effort is a complex mix of internal NWS activities and multiple contractor efforts. Internal activities provide land, facilities, software, training, staffing, and new operational procedures.

Modernization and Associated Restructuring. The NWS has begun this process of change prompted by two factors: the need to apply advances in hydrometeorological science and technology to operational forecasting and the need to replace obsolete and increasingly unreliable equipment. These factors offer the opportunity to improve severe weather warnings, flood warnings, and forecasts through the acquisition of the following new technologically advanced systems:

- Automated Surface Observing System (ASOS) to reduce time-consuming manual observations, provide continuous weather watch, and permit increased productivity of staff (Figure 3-DOC-4).
- Next Generation Weather Radar (NEXRAD) with Doppler capability and sophisticated software to provide nationwide coverage for timely and accurate detection of severe weather and floods.
- Advanced Weather Interactive Processing System (AWIPS) to enable local forecasters to integrate, process, and transmit high-volume radar, satellite, upper air, surface observation data and guidance information.
- Computer Facility Upgrades to accommodate advanced numerical weather prediction models and increased data to improve accuracy of forecast guidance.

These systems upgrades, coupled with observations from planned, advanced geostationary and polar-orbiting satellites and newly developed mesoscale forecasting techniques, will greatly improve the timeliness and accuracy of severe weather and flood warnings to the public. Improved capability to detect and predict the small-scale, short-lived (mesoscale) phenomena which cause the most destructive weather events will increase warning lead times for severe thunderstorms, tornadoes, high winds, and flash floods, as well as reduce false warning.

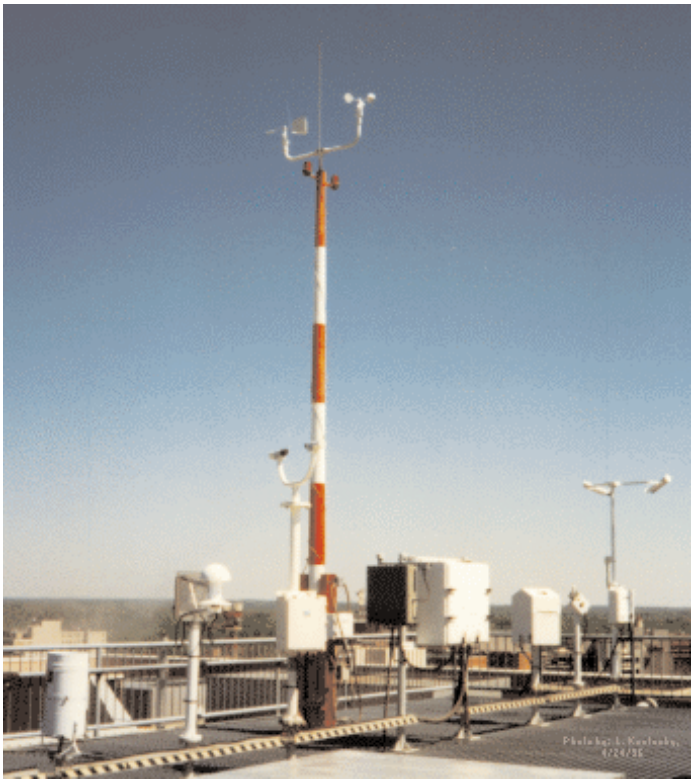

Figure 3-DOC-4. ASOS Data Collection Package (DCP)

The National Environmental Satellite, Data, and Information Service (NESDIS) manages United States civil operational environmental satellite systems, as well as global databases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and development and management of environmental resources.

NESDIS was established as a NOAA line office on December 1, 1982. It was formed by the merger of the former National Environmental Satellite Service (NESS) and Environmental Data and Information Service (EDIS).

NESDIS operates two primary polar-orbiting satellites in sun-synchronous orbits with equatorial crossing times in the early morning (circa 7:30 a.m. LST) and early afternoon (circa 1:40 p.m. LST). These satellites collect global data four times per day that provide atmospheric and surface measurements in support of short-term weather forecasting and longer-term global climate change research. An agreement finalized with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of the polar environmental mission (circa 9:30 a.m. LST), with United States-provided payload instruments and sensors, beginning in 2003. Thus, upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission.

On October 3, 1994, NOAA, DOD, and the National Aeronautics and Space Administration (NASA) created an Integrated Program Office (IPO) to develop, manage, acquire and operate the national polar-orbiting meteorological satellite system, subsequently designated the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IPO is organizationally located within NOAA and is headed by a System Program Director responsible to the NPOESS Executive Committee. This committee, which includes senior representatives from the three agencies, serves as a board of directors to ensure that the overall program plans meet the needs of the three participating agencies.

The IPO concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DOD is responsible to support the IPO for major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach.

The first converged satellite is expected to be available sometime toward the middle to latter half of the next decade depending on when the current NOAA and DMSP programmed satellite assets are exhausted. NPOESS will provide standard meteorological data, oceanographic, environmental, climatic, space environmental remote sensing information, as well as continuing to provide surface data collection and search and rescue capability. The IPO, in consultation with the NOAA and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services.

NESDIS is also responsible for operating two Geostationary Operational Environmental Satellites (GOES). GOES-East stationed at 75°W monitors the Atlantic Ocean, the East and Gulf Coasts, and the Midwest; GOES-West at 135°W monitors the Pacific Ocean and West Coast.

Due to an impending failure of the attitude and orbit control systems on GOES-9, it was replaced by GOES-10 in July 1998. GOES-L, the next in the series of GOES, is scheduled for launch in May 1999.

ENVIRONMENTAL SATELLITE SERVICES

The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) and Command and Data Acquisition (CDA) stations, which command and control, track, and acquire data from these environmental satellites (see Figure 3-DOC-5 and Figure 3-DOC-6 for details)

OSO took over the command, control, and communications function of the DOD's Defense Meteorological Satellite Program (DMSP) constellation in 1998. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide DOD missions. DMSP is now operated from the Satellite Operations Control Center (SOCC) at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution. A new ground system was developed for DMSP called Integrated Polar Acquisition and Control Subsystem.

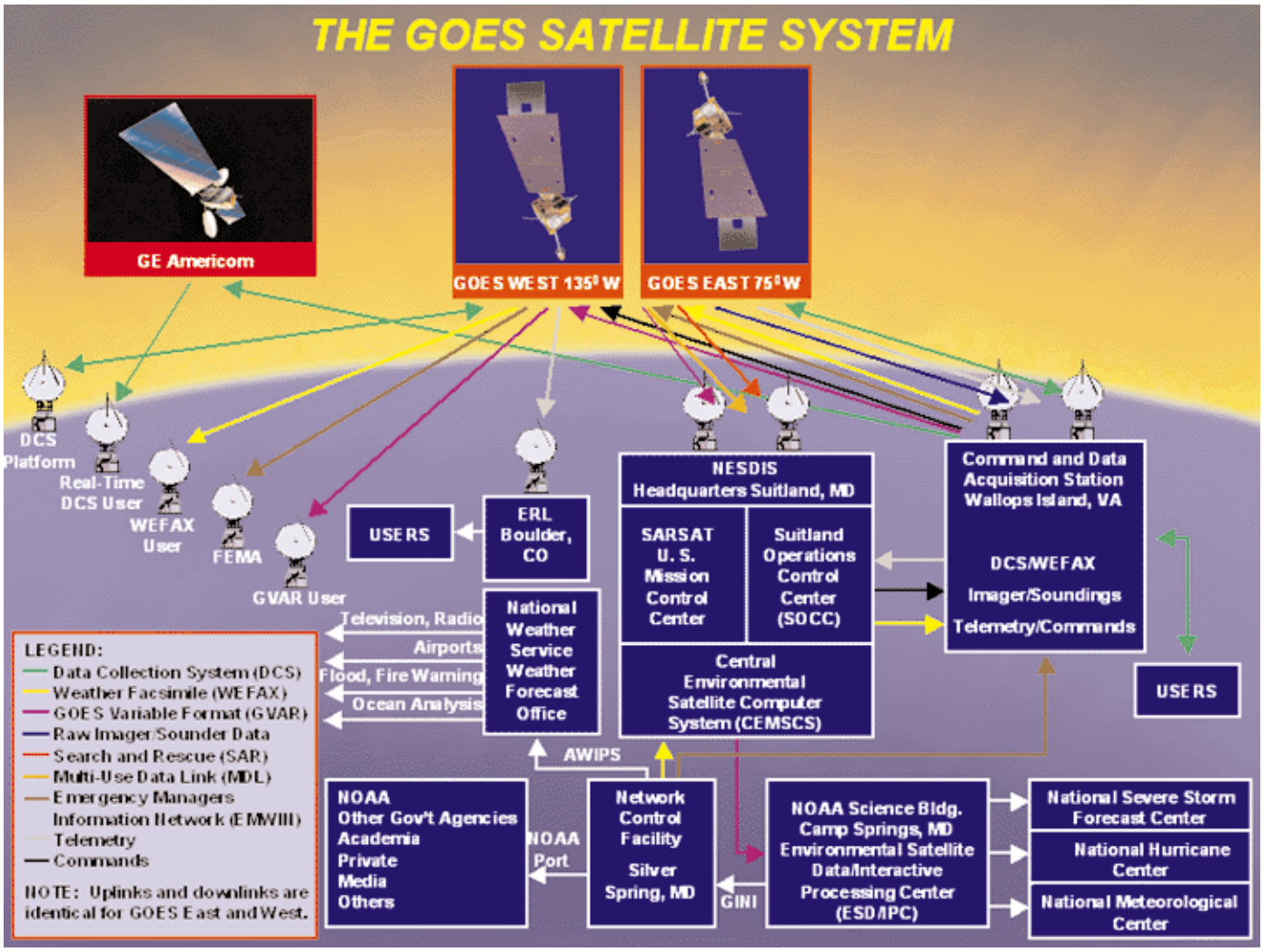

Figure 3-DOC-5. Diagram of Geostationary Operational Environmental Satellite (GOES) command/control and data communications.

The Office of Satellite Data Processing and Distribution (OSDPD) directs the operations of NESDIS central ground data processing facilities. It processes and distributes current weather satellite data and derived products to the NWS and other domestic and foreign users.

OSDPD distributes NOAA and non-NOAA environmental satellite products to the NWS Satellite Field Distribution Facilities (SFDF), who provide further distribution to regional NWS offices and other federal, state, and private sector agencies. At the end of FY 1998, OSDPD decommissioned GOES-TAP, an analog distribution service. As a replacement, OSDPD is currently generating modern remapped digital data satellite products for further distribution via NOAAPORT, a satellite point to multi-point broadcast. NOAAPORT will deliver various GOES products in virtually real-time to the AWIPS. AWIPS, a new workstation, enables NWS field sites to integrate and display satellite data for hydrometeorological analyses.

As AWIPS development and deployment proceed, NESDIS will continue to supply digital GOES images to a group of NWS sites equipped with the RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (RAMSDIS)--a PC-based image display and analysis system. These sites acquire the images via the Internet for demonstration, evaluation, and familiarization purposes. RAMSDIS enables forecasters to perform operations such as looping, enhancement curve changes, and local image recombination.

NESDIS continued its support of the COSPAS-SARSAT Program through provision of satellites, ground stations, and alert data distribution services. Russia, the United States, France, and Canada provide the space segment and related ground systems for COSPAS-SARSAT. NOAA operates and maintains the United States SARSAT Mission Control Center and seven ground stations. The ground stations receive Doppler signals directly from the satellites and process the information to provide the location of distress transmissions.

COSPAS-SARSAT planned to incorporate Geostationary Earth Orbit Search and Rescue (GEOSAR) satel-

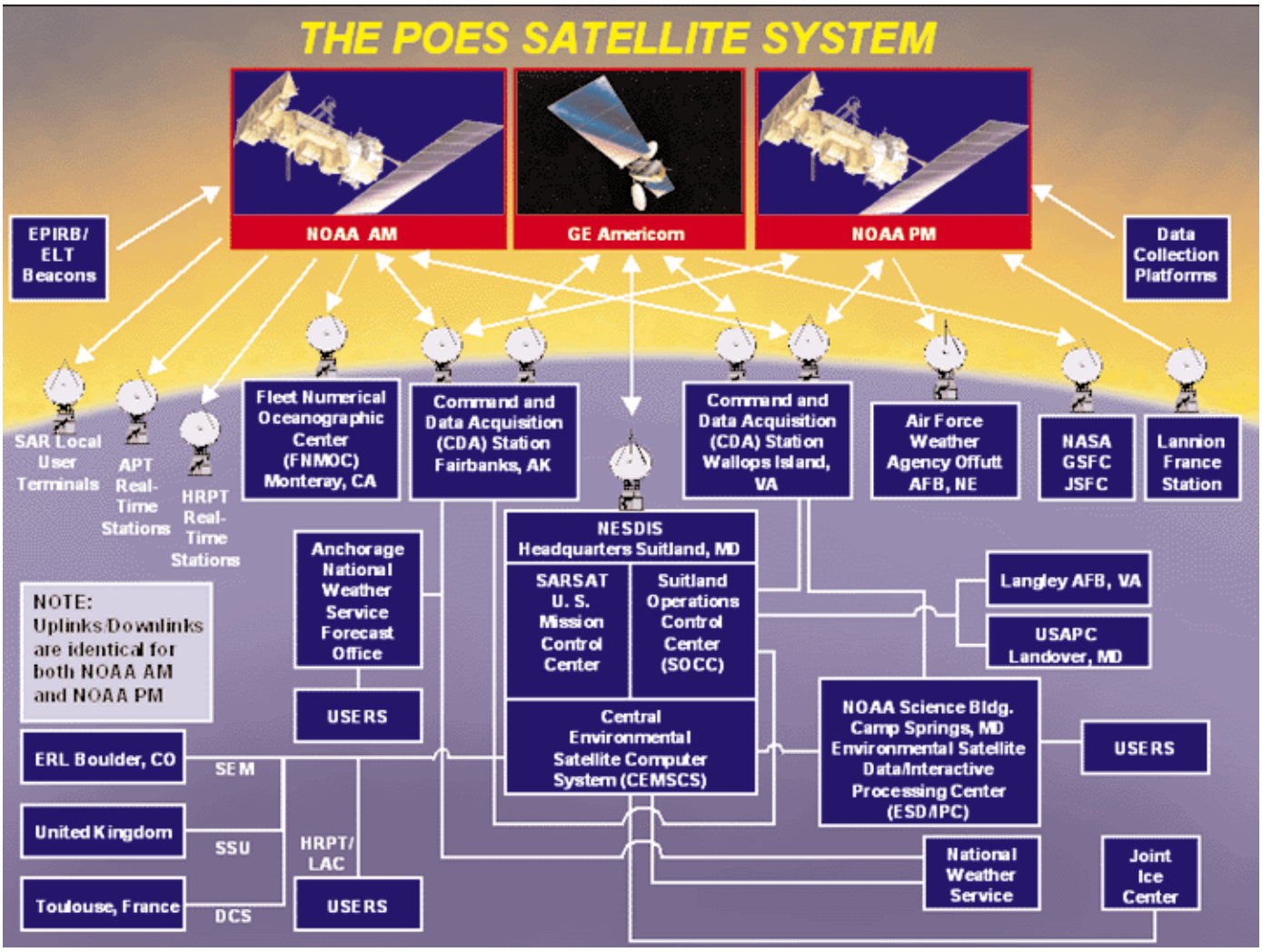

Figure 3-DOC-6. Diagram of Polar-Orbiting Operational Environmental Satellite (POES) command/control and data communications.

lite systems as a supplement to the existing COSPAS-SARSAT polar-orbiting system by late 1998. GEOSAR systems will provide instantaneous alerting capability and could significantly decrease rescue times. In 1998, the COSPAS-SARSAT Council also agreed to implement new emergency beacon location protocols to provide precise location within the beacon message using the United States Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS).

Arctic Drifting Buoy Program. The United States Interagency Arctic Buoy Program (USIABP) was established in 1992 to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of eight government agencies and/or programs. These organizations include: the Naval Oceanographic Office, ONR, NASA, NSF, and NOAA's NESDIS, OAR, and Office of Global Programs (OGP).

The Office of Research and Applications (ORA) provides guidance and direction for NESDIS research and applications activities. It coordinates the efforts of the Climate Research and Applications Division, Atmospheric Research and Applications Division, and Oceanic Research and Applications Division. These divisions conduct studies on the use of satellite data to monitor environmental characteristics and change and develop algorithms to produce satellite products for applications to operational weather and ocean analyses and prediction. Further, ORA participates in the development of new spacecraft and sensors for future systems. It also carries out a vigorous program to calibrate and validate satellite data to ensure its quality for long-term studies. Staff from these divi-

sions also conduct a strong technology transfer program through scientific presentations, technical reports, Internet-based tutorials, and training workshops at domestic and international sites.

Polar-Orbiting Systems

The primary mission of the Polar-Orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe.

These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-15 and NOAA-14. NOAA polar satellites carry instruments to provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system, and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users. In addition to taking thermal images of the earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

The NOAA-series satellites carry four primary instrument systems. The Advanced Very High Resolution Radiometer (AVHRR) provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR instrument provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, and snow and ice mapping.

NOAA-15 carries the first of a new generation of imager and sounder. The AVHRR on NOAA-15 contains a switchable Channel 3A (1.6 micrometers (µm)) and Channel 3B (3.7µm). In addition, NOAA-15 carries the first Advanced TOVS.

ATOVS consists of the High Resolution Infrared Radiation Sounder (HIRS/3), an Advanced Microwave Sounding Unit-A (AMSU-A), and the Advance Microwave Sounding Unit-B (AMSU-B), replacing the Microwave Sounding Units (MSU) and the Stratospheric Sounding Units (SSU) flying on the older polar-orbiting satellites. The new AMSU instruments are designed to provide increased accuracy in temperature and humidity retrievals. They will receive a thorough post-launch calibration and evaluation. This will include checking instrument performance against specifications and comparing with pre-launch test results. Long-term trends of the various instrument and blackbody temperatures will also be determined.

The HIRS/S is a discrete stepping, line-scan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40 kilometers (km).

Multispectral data from one visible channel (0.69µm), seven shortwave channels (3.7 to 4.6µm) and twelve longwave channels (6.5 to 15µm) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8µ. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place each 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4µ in the visible and shortwave IR and 1.3µ in the longwave IR band which, from an altitude of 833 km, encompasses an area of 20.3 km and 18.9 km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: AMSU–A2 with two channels at 23.8 and 31.4 GHz; and AMSU-A1 with twelve channels in the range of 50.3 to 57.3 GHz and one channel at 89.0 GHz. The AMSU-B has five channels with frequencies centered on 89, 150, and 183±1, 183±3, and 183±7 GHz, respectively. AMSU-B, which is provided by the United Kingdom Meteorological Office. The ANSU-B provides soundings of humidity from surface to 200 millibars (mb). AMSU–A has a nominal FOV of 3.3° (48 km on surface at nadir) and AMSU-B a field of view of 1.1° (16 km on surface at nadir). AMSU-A (AMSU-B) samples 30° (90) Earth views, covering ±48.95° from the sub-satellite point. In addition, the specialized 89 GHz channel, with the capability to "see" through high and mid-level clouds to low level moisture clouds, is being utilized to determine the position and structure of tropical cyclones on a global scale.

The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42 kilometer (km), or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) will aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

The Space Environment Monitor (SEM) measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitude. The two sensors included within this instrument are the Total Energy Detector (TED) and the

Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

In addition to the four primary instrument systems, the "afternoon" NOAA series spacecraft carry the Solar Backscatter Ultraviolet Radiometer (SBUV/2). SBUV/2 is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems--the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, CDA stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland.

PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDAs to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed on to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions which are disseminated to users throughout the world.

POES Data Collection

The Data Collection System (DCS) is provided through an international cooperative agreement with the Centre Nationale d'Etudes Spatiales of France and is called the ARGOS DCS. The system provides a means to locate and collect environmental data from fixed and moving platforms i.e. buoys, wildlife, etc. The ARGOS DCS supports environmental applications, e.g. meteorology, oceanography, and protection of the environment, with the majority of users being government/ non-profit agencies and researchers. An instrument upgrade to incorporate a downlink message capability is planned for the NOAA-N' satellite. A new regulation entitled *Policies and Procedures Regarding Use of the NOAA Space-Based Data Collection Systems* (CFR 15 Part 911) was published on May 6, 1998.

Geostationary Satellite Program

Two operational geostationary satellites, GOES-8 (75°W) and GOES-10 (135°W), now cover virtually the entire western hemisphere for operational meteorological services. New operating schedules allow acquisition and distribution of imagery from the satellites four times per hour over much of North America in Routine mode, and eight times per hour over the contiguous United States to monitor dynamic weather and land events, such as fires and volcanoes.

The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1.

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA L	CY 2000
NOAA M	CY 2001
METOP-1	CY 2003
NOAA-N	CY 2003
METOP-2	CY 2008
NOAA-N'	CY 2008
NPOESS-1	CY 2009
NPOESS-2	CY 2010
METOP-3	CY 2012
NPOESS-3	CY 2014
NPOESS-4	CY 2016
NPOESS-5	CY 2018

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES L	CY 1999
GOES M	CY 2002
GOES N	CY 2002 (Failure)
GOES O	CY 2005
GOES P	CY 2007
GOES Q	CY 2010

*Launch date depends on performance of prior spacecraft and is subject to change.

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE (cont.)

NOAA Instruments for NOAA Polar-Orbiter and METOP Series	
AVHRR	Advanced Very High Resolution Radiometer
SEM	Space Environment Monitor
SBUV	Solar Backscatter Ultraviolet Radiometer (NOAA PM mission only)
HIRS	High Resolution Infrared Sounder
DCS	ARGOS Data Collection System
AMSU-A	Advanced Microwave Sounding Unit-A
AMSU-B	Advanced Microwave Sounding Unit-B
SARP	Search and Rescue Processor
SARR	Search and Rescue Repeater
MHS	Microwave Humidity Sounder (NOAA-N/N' and METOP
Instruments for NPOESS Series	
VIIRS	Visible/Infrared Imager/Radiometer Suite
CMIS	Conical Microwave Imager/Sounder
CrIMSS	Cross-track Infrared/Microwave Sounder Suite
OMPS	Ozone Mapper/Profiler Suite
SES	Space Environment Suite
DCS	Data Collection System
SARSAT	Search and Rescue Satellite Aided Tracking System
ERBS	Earth Radiation Budget Sensor
TSIS	Total Solar Irradiance Sensor
ALT	Altimeter (Dual Frequency radar altimeter)
Instruments for GOES-Next Series	
Imager	
Sounder	
SEM	Space Environment Monitor
SXI	Solar X-Ray Imager (GOES L or M)
SAR	Search and Rescue
DCS	Data Collection System
EUMESAT Unique Instruments for METOP Series Satellites	
ASCAT	Advance Scatterometer
GOME	Global Ozone Monitoring Experiment
GRAS	GPS Receiver for Atmospheric Sounding
IASI	Infra-red Atmospheric Sounding Interferometer

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 micron (μ) and 12.0μ wavelengths. GOES satellites transmit all five spectral bands simultaneously, affording the user community continuous views of atmospheric measurements in various wavelengths, each with its own meteorological and hydrological application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled within a 30–minute time frame. For example, the full earth disk is scanned once every three hours and requires the entire 30-minute time period. Depending on the severity of the land or atmospheric event being monitored, 30-minute periods in between the full disk scans may be a mixture of 15–minute interval (routine operations) or 7½ minute interval (severe operations) scans over the contiguous United States. To further support mesoscale and microscale analyses, 1000 km x 1000 km coverage can also be scanned at one minute intervals to capture rapidly developing and dynamic environmental phenomena.

The five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55μ to .75μ)–1 km.
- Channel 2 (Infrared, 3.8μ to 4.0μ)–4 km.
- Channel 3 (Water Vapor, 6.5μ to 7.0μ)–8 km.
- Channel 4 (Infrared, 10.2μ to 11.2μ)–4 km.
- Channel 5 (Infrared, 11.5μ to 12.5μ)–4 km.

The GOES-8 and GOES-10 sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index--a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverages, such as full Earth imagery, sectorized imagery, and local imagery. An independent sounder platform, governed under its own schedule, leads to an expansion of sounder-data coverage and an increase in the frequency of transmissions.

GOES Data Collection

The GOES also carries a Data Collection System (DCS) which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gages, seismometers, buoys, ships, and automatic weather stations. Data collection platforms offers many ways to monitor the atmosphere, the earth's water from rain and its runoff, the forest growth and susceptibility to fire, the stresses of the earth's crust, the oceans' surface and mixed layers, the parameters affecting agricultural production, and the quality of air and water. Many of the federal agencies have their own data collection networks for collecting and telemetering their data for their own use. The GOES DCS has become the conduit through which remotely sensed data, the life-blood of the agencies' operations, must pass. In support of agency missions, the GOES DCS data are used in weather forecasts and warnings, reservoir control and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the NWS' NEXRAD program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the DCP data transmitted via GOES DCS. The GOES DCS program touches all aspects of our lives in supporting water quality, air pollution, and global environmental monitoring.

Data are collected for warnings of solar activity using SEM. This block of instruments is more extensive than on the polar spacecraft. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three-component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on-line via Internet and on a variety of computer media.

A system similar technically to the DCS, but used for a different purpose, is the SARSAT transponder. The operational SARSAT transponders on GOES-8 and GOES-9 are capable of providing an immediate distress alert. While the present GOES system is incapable of providing location of the distress signal, it provides advance warning to the SARSAT Mission Control Center which then begins to verify the location of the alert through other means. Future COSPAS-SARSAT distress beacons, utilizing Global Positioning System (GPS), will have the capability to provide location information in the distress message.

Satellite Communications System (SATCOM)

The NESDIS Telecommunications System is a complex network of voice, teletype, and data-grade transmissions sent via satellites, microwave, and terrestrial cable services. A major component of the system is the Office of Satellite Operations (OSO) which consists of the SOCC and two CDA stations at Wallops, Virginia, and Fairbanks, Alaska. OSO is responsible for the operation and safety of NOAA polar and geostationary satellites and for providing satellite data to OSDPD.

Another major component is the Environmental Satellite Distribution/ Interactive Processing Center (ESD/IPC) in Camp Springs, Maryland. The ESD/IPC is connected in turn with the Fairbanks and Wallops CDA stations and the six SFDFs.

A third major component, managed and operated by OSDPD and NOAA's National Climatic Data Center (NCDC), is the NOAA Operational Satellite Active Archive (SAA) for satellite data and metadata access, display, and electronic transfer. The SAA offers the user a wide range of capabilities, including data catalog and inventory search, AVHRR image browse, on-line data selection and file transfer protocol (FTP), and off-line data selection and delivery. On-line system documentation, data guides, and help files will assist the novice user and provide valuable time-saving tips to all users. While developed as an independent system, the SAA serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). In 1997, DMSP special sensor products and RADARSAT products for authorized subscribers, were made available to users.

SUPPORTING RESEARCH PROGRAM

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP/EMC and other major International NWP Centers, require higher quality satellite derived winds, particularly over the traditionally data void oceanic regions of the globe. In March 1998, NOAA/NESDIS implemented an upgraded operational wind production suite which provides higher quality imager-based cloud-drift and water vapor motion winds at significantly increased spatial and temporal resolution. The system is totally automated and uses a series of geostationary satellite images to derive wind estimates. Automated quality control of the

image registration is a new and important addition to the NESDIS GOES winds processing suite. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. With increased computer resources, a ten-fold increase in the yield of "good" wind vectors for GOES-8 and GOES-10 are being generated every 3 hours for the Northern and Southern Hemisphere. Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunication System (GTS). EMC now uses these new operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems.

Recent work involves: (1) the development of a dual pass quality control capability which allows for the retention of satellite winds in the vicinity of tropical storms where the accuracy of global forecast wind fields is lacking; (2) the development and validation of a cloud-base height estimation technique which assigns the height of cloud tracers to cloud base rather than to cloud top; (3) development of a new low level IR targeting strategy aimed at increasing the number of low level cloud drift winds in areas covered by persistent, low level cloud regimes; and (4) the formatting of the wind products into the WMO sanctioned BUFR format. New satellite wind products being developed and validated include the low level high density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower-tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0µm and 7.3µm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0µm channel peaks around 450mb and the weighting function of the 7.3µm channel peaks around 550mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in the end of March 1999. These wind products can be viewed at *http://orbit-net.nesdis.noaa.gov/goes* and *htttp://cimss.ssec.wisc.edu/tropic/real-time.*

Atmospheric Moisture and Stability Products

Research continues to improve the atmospheric moisture and stability products from the GOES-8 and GOES-10 sounder instruments. Precipitable water for three layers of the atmosphere: surface to 900 hPa; 900-700 hPa; and 700-300 hPa are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the earch's surface to the "top" of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation, locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this information provides useful information for the EMC regional data assimilation systems and for weather forecasters out in the field. EMC currently uses the GOES precipitable water retrievals as input to ETA Data Assimilation System (EDAS) which provides the initialization for the ETA forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes. At present, a blended GOES, SSM/I, and model-derived product is being evaluated. In addition, a PW product has been developed from the NOAA-15 AMSU sensor, and is presently undergoing evaluation. In the near future, the blended product will include the AMSU-derived PW.

In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events. So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field, for example, to understand the time evolution of severe storms.

It is anticipated that the GOES sounder moisture and stability products which presently have a horizontal resolution of approximately 50 km^2, will be generated at a high horizontal resolution of 30 km^2 by the summer of 1999. These products can be viewed at *http://orbit-net.nesdis.noaa.gov/goes* and *htttp://cimss.ssec.wisc.edu*.

Precipitation Estimates

The Auto-Estimator produces half-hourly estimates of precipitation based on GOES infrared data. This technique was devised to replace the more manual "Interactive Flash Flood Analyzer" (IFFA). The Auto-Estimator has an

orographic adjustment factor and can be manually adjusted for warm cloud tops. Current improvements being tested include using: 15-minute images, radar and visible data (as a rain/no-rain detector) and equilibrium level temperatures from the ETA model for warm top adjustments. Other techniques are being tested such as the GOES Multi-Spectral Rainfall Algorithm (GMSRA), a combined GOES and SSM/I rainfall algorithm (developed at NRL/Monterey), and a NOAA-15 AMSU based retrieval algorithm. The GMSRA uses all five GOES imager channels and may be merged with the Auto-Estimator after the intercomparison is completed. Finally, the POES based microwave algorithms from the SSM/I and AMSU sensors are being utilized to produce automated tropical cyclone rainfall potential estimates and global precipitation estimates are produced from microwave data for climate monitoring and analysis.

Microburst Products

Several experimental microburst and convective wind gust products are being tested. These products utilize sounder data from both GOES-East/West to compute the maximum possible wind gust and the potential for both wet and dry microbursts over the continental United States. They are produced hourly during the convective season and can be viewed at: *orbit-net.nesdis.noaa.gov/arad/fpdt/mb.html*.

Low Cloud and Aircraft Icing Products

Detection of fog and low clouds, particularly at night, is important to aviation activities. A GOES product utilizing two infrared channels (10.7mm and 3.9mm) can help determine the areal extent of this cloudiness at night over the continental United States and Alaska every 30 minutes. An experimental fog depth image is produced hourly. Fog products can be found at: *orbit-net.nesdis.noaa.gov/arad/fpdt/fog.html*. By combining information from the visible and longwave infrared (12.0mm) channels to the two described above, areas of possible aircraft icing can be delineated. The icing product is available hourly and can be viewed at *orbit-net.nesdis.noaa.gov/arad/fpdt/icg.html*

Geostationary Sea Surface Temperatures

GOES-8/9/10 are proving capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar orbiting platforms and GOES has a unique advantage of high temporal sampling frequency. For the SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Cloud detection is enhanced by noting that a change in scene temperature over a short period of time may indicate the presence of clouds. The abundance of GOES observations helps to maintain a balance between high quality cloud free observations and good geographical coverage of SST estimates. For the first time, GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long periods of time. This quantification may have important implications in both numerical weather prediction and climate monitoring. NOAA/NESDIS has been producing the GOES SST hourly since December 1998. An experimental GOES SST product is being produced from GOES-8 and GOES-10 imager visible and infrared channels. Global SST product is produced every three hours; regional SST products are generated every hour. These products are being evaluated for operational implementation in January 2000.

Volcanic Ash Monitoring

Techniques that use the imager and sounder channels on GOES-East/West are being developed to assist in the tracking of volcanic ash cloud plumes. One product that employs three channels (10.7mm, 12.0mm and 3.9mm) has been developed and is under evaluation by NESDIS operations. Ash cloud advisory statements are provided by NESDIS operations to the aviation community over southern North America and northern South America. The experimental volcanic ash product is produced hourly for several active volcanic areas and made available on the Web at: *orbit-net.nesdis.noaa.gov/arad/fpdt/volc.html*.

Fire and Smoke Monitoring

Algorithms are being developed to detect fires and to monitor their growth and the associated smoke coverage. The GOES-8 split window data (at 4μ and 11μ) have been used to assess trends in South American burning practices over the past four years (June through October of 1995 through 1998); GOES detected the most fire pixels in the tropical rain forest ecosystem in 1997. The application to clear sky human-initiated burning in South and Central America is now being adapted to monitor cloudy sky lightning and clear sky human-initiated fires in the Canadian provinces and the continental United States. The continual monitoring from GOES (as often as every 7.5 minutes) can assist firefighters plan evacuation and extinguishing activities (see Figure 3-DOC-7). NESDIS will be testing routine production of a fire product in fall 1999. An Advanced Very High Resolution Radiometer (AVHRR) fire detection algorithm is being developed for use in monitoring fire and smoke outbreaks around the world. This algorithm is being implemented in a Hazard Mapping System that will provide analysts a means to look at fire and smoke events as well as other environmental hazards, and provide the data to users and the media.

NPOESS

ORA continues to support the IPO in acquisition of the next generation instruments for NPOESS. ORA scientists continue to play an important role in the evaluation of proposed contrac-

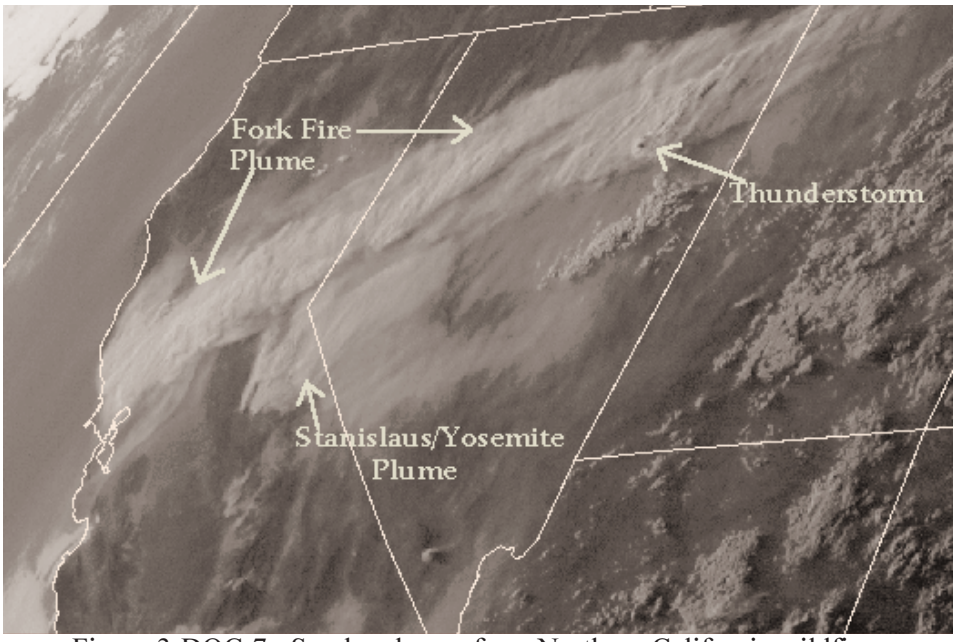

Figure 3-DOC-7. Smoke plumes from Northern California wildfires (GOES-8 Enhanced VIS)

tor sensor design and retrieval methods during the ongoing selection process. ORA scientists have created a variety of "test bed" data sets that are being used in the algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the Environmental Data Records spelled out in all IPO documentation.

Ozone

Evaluation, calibration, and validation activities will take place for the new Solar Backscatter Ultraviolet Spectrometer/2 (SBUV/2) instrument after the launch of NOAA-L in early 2000. A new ozone profile retrieval algorithm (Version 7) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-11, -14, and -L, and with the Television and Infrared Operational Satellite (TIROS) Operational Vertical Sounder (TOVS) instruments on NOAA-14, -15 and -L. The late-1998 Antarctic ozone "hole" was the largest (in area) ever observed, over 26 million square kilometers at its peak. The hole lasted into late December, making it one of the longest-lasting of those observed in recent years.

Land Surface Parameters for Use in Weather Forecast Models

Satellite-derived fields of land surface characteristics are being prepared for use in NWP models. These include radiation products delivered in near real time as forcing variables, surface characteristics such as fractional green vegetation and albedo that specify model lower boundary conditions and validation quantities such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness and development of snow depth is underway. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models.

Clouds from AVHRR

Algorithms are being developed, tested, and validated for determining cloud optical and microphysical properties from imager data such as the Advanced Very High Resolution Radiometer (AVHRR) instrument. These algorithms are in addition to those already developed which estimate amounts and types for each observed cloud layer. The four cloud types are: L - Liquid Water Clouds; M - Mixed Phase Clouds; G - Glaciated Clouds (opaque); H - High Ice Clouds (semi-transparent). Knowledge of cloud properties is important for both climate-scale and short-medium range forecasts. Accordingly, algorithms and processing systems to estimate cloud properties from imager data are being developed for both applications. Assimilation of cloud properties into NWP models is an objective of the NCEP for improving short-medium range forecasts. Other applications of this work include the validation of simulated scenes to be used for evaluation of new algorithm and instrument designs which is supported by the IPO. In addition, new algorithms are being developed to produce optimal estimates of cloud properties from both imager and sounder data such as the merge of the AVHRR and TOVS (TIROS Operational Vertical Sounder) data.

Aerosols

An algorithm for the correction of a thermal radiation leak in the 1.6μ reflectance channel of the Tropical Rainfall Measuring Mission (TRMM) satellite's Visible Infrared Scanner (VIRS) has been developed. It is being applied to VIRS raw data prior to application of the NESDIS operational aerosol retrieval algorithm by NASA's Clouds from the Earth's Radiant Energy System (CERES) instrument data processing team. Without this correction, the aerosol optical thickness at 1.6μ would be overestimated by as much as 200 percent, depending on the temperature of the Earth's surface.

In FY 2000, we will validate retrievals of aerosol optical thickness (AOT) and the Angstrom Exponent, a measure of the size of particles in the atmospheric column derived from optical thickness measurements at 1.6µ, and 0.63µ, the other reflectance channel of VIRS. Validation will be accomplished by comparison with sun-photometer measurements of solar extinction at five wavelengths from 15 island and coastal locations established by NASA's Aerosol Robotic Network (AERONET). This algorithm will also be applied to NOAA-L AVHRR data (after its launch in early 2000) which has the same two reflectance channels as VIRS plus an 0.83µ reflectance channel. This information on aerosols will be used to correct for the attenuation of aerosol particles in the infrared channels of the AVHRR instrument to remove errors in the retrieval of sea surface temperature. The correction algorithm will initially be derived from the multi-year archive from the AVHRR Pathfinder Atmosphere (PATMOS) data set using a single channel AOT retrieval at 0.63µ. The long-term record of AVHRR SSTs can be corrected for aerosol induced errors which currently limit the utility of these data for climate change studies. Finally, an algorithm for the estimation of aerosol optical thickness over dark vegetated land surfaces will be developed in support of NASA's Global Aerosol Climatology Project (GACP). It will also utilize the PATMOS archive of clear-sky reflectances at 0.63µ collocated with sun-photometer observations of AOT at non-coastal land based AERONET stations to make empirical adjustments to the surface reflectance model used in the NOAA/NESDIS operational aerosol retrieval algorithm used over oceans. This will be the first globally applicable aerosol retrieval algorithm for land areas and will be used by NASA and NOAA to create a climatology of aerosol optical thickness over land for climate change studies.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance

Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the Central Environmental Meteorological Satellite Computer System (CEMSCS) at NESDIS and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NOAA have already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications, and in some channels it is lower than estimates based prelaunch test results. In FY 2000, NOAA will examine the other radiometric parameters. We will also continue compiling long-term trends of all the parameters to provide us with a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the Advanced Very High Resolution Radiometer

The AVHRR flown on NOAA's Polar-Orbiting Operational Environmental Satellites (POES) is recognized as an invaluable resource for satellite-based studies of the Earth system. The long-term records of geophysical products such as the Normalized Difference Vegetation Index (NDVI), columnar aerosols over the oceans, cloud morphology, and short-wave radiation budget play a central role in climate and global change studies by providing a means to study the environment continuously. It is thus very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible (Channel 1: 0.58 - 0.68 µm), and near-infrared (Channel 2: 0.72 - 1.1 µm; Channel 3A: 1.58 - 1.64 µm) channels which do not have any onboard calibration devices. The major program elements are: (a) development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft; (b) enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ± 5 percent; (c) evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST); (d) establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors such as the imager on the Geostationary Operational Environmental Satellite (GOES), the visible channel of the High-resolution Infrared Radiation Sounder (HIRS), the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and (e) design of optimal onboard and vicarious calibration techniques for the visible and near-infrared sensors planned under the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV), Committee on Earth Observation Satellites (CEOS), and the Global

Observing Systems Space Panel (GOSSP). To ensure global access to the results of the above program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems (G3OS), and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in the National Aeronautics and Space Administration (NASA), NIST, European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the United States, and academia both in the United States and abroad. Accomplishments to date include near-real time updating of the calibration of the AVHRR on NOAA-14; determination of the in-orbit degradation of the AVHRR on NOAA-15 within six weeks after launch, and the evaluation of the performance of the visible channel of HIRS on NOAA-14, using the AVHRR as a calibration standard. Dissemination of the information resulting from the calibration activity is accomplished through presentations at the meetings of learned and professional societies, publications in the literature, and through the electronic media.

Calibration of Geostationary Operational Environmental Satellite Instruments

The wavelength configuration of channels on the Geostationary Operational Environmental Satellite-M (GOES-M) Imager (due for launch in CY 2002) will be slightly different from that of its predecessors. The current 12µm channel will be replaced by one at 13.3µm. The new channel will employ a single detector with an 8-km field-of-view at the Earth's surface. The water-vapor channel at 6.7µm, which on GOES I-L observes the Earth with a single 8-km detector, will employ two 4-km detectors on GOES-M. To accommodate these revisions, the calibration processing in the ground system will be modified. Radiometric testing of the instruments on GOES-N and later satellites will begin in late FY 1999 at the facilities of their manufacturer, ITT. During FY 2000, the test data will be analyzed to characterize radiometric performance. The feasibility of a star-based technique to measure the degradation of the responsivities of the visible channels of the GOES Imagers is being tested in FY 1999. If successful, the technique will be made operational in FY 2000.

Pathfinder

Climate data sets of cloud amount, aerosol optical thickness (AOT) over the oceans, and the Earth's radiation budget for clear and cloudy skies have been retrospectively generated from over 17 years of AVHRR data as part of the NOAA-NASA Pathfinder program. Processing was temporarily halted after the generation of August 1998 data products due to the fact that the processing code is not Y2K compliant. Work to rectify this problem is underway as well as to put in other fixes that will improve the accuracy and quality of the data products. Resumption of the processing and implementing the fixes are expected by September 1999. An improved data set spanning the period from July 1981 through the end of 1999 should be available around January 2000. The current data set is being utilized to study the relationship between the variation in global mean values of the absorbed solar radiation and variation in aerosol amount caused by major volcanic eruptions. The influence of the aerosol amount on variations in the global surface temperature is also under investigation. Analysis of time series of anomalies of the cloud radiative forcing have been shown to correlate well (spatially and temporarily) with El Niños. A second reprocessing of the entire data set is being proposed, where multiple-layered cloud data will be used. The cloud data will be available in the very near future. Land surface and ocean products such as the vegetation index and the sea surface temperature will be added.

Ocean Surface Winds

Calibration and validation studies are performed for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future that NOAA will have the opportunity to obtain near real-time data streams from. One of these sensors will be the first demonstration of the passive polarimetric technique, which is the technique that is being depended on for the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) to meet the nations ocean surface wind vector requirements.

Storm Signatures and Winds from Synthetic Aperture Radar

ORA scientists are currently studying ocean surface wind signatures of atmospheric fronts and storms with synthetic aperture radar (SAR) imagery. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as coastal lee waves), atmospheric fronts, and coastal wind shadowing. Techniques for calculating wind speed (and under certain conditions direction as well) are also under development. A

near real-time demonstration of SAR applications in Alaska is planned to begin in the fall of 1999 using data from the Canadian RADARSAT satellite. SAR images of the Bering Sea and northern Gulf of Alaska will be provided to the NWS Anchorage WFO for analysis of wind conditions, location of polar lows, and position of the ice edge. Wind speed images derived from SAR will also be provided along with other wind data such as scatterometer winds to allow meteorologists at the Anchorage office to assess the utility of SAR data and derived products to their operational weather analysis and forecast activities. Before the year 2003, four new wide-swath SAR satellites are planned for launch. If data acquisition and sharing arrangements can be made to obtain access to SAR imagery from this new constellation of satellites, frequent routine SAR coverage of United States coastal areas will be possible.

Ocean Color

Several programs at ORA are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys, and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near-infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the soon to be launched Moderate Resolution Imaging Spectroradiometer. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection of *in situ* measurements of these and other parameters relevant to ocean color in the surrounding region from ship. Data from both sampling platforms furnish a time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at ORA to routinely evaluate the accuracy of NOAA/NESDIS operational ocean color products and to develop algorithms in order to remotely detect and predict the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch: NOAA's Early Warning System for Coral Reef Health

Like the rest of the world, most of the United States coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's, and an unknown but significant fraction of United States Pacific Territories. The widely-distributed and isolated location of many coral reefs preclude normal monitoring practices. In 1998, NESDIS established an experimental capability using NOAA (AVHRR) satellites to conduct thermal bleaching surveillance of coral reefs on a world-wide basis. This experiment demonstrated remarkably accurate capabilities for early warning of El Niño-induced coral reef bleaching conditions over all global tropical ocean regions resulting in a special International Workshop on Satellite Monitoring of Coral Reefs being convened in June 1999. A Coral Reef Watch Program was proposed to (1) transition existing experimental satellite reef health monitoring capabilities into a viable operational capability, (2) formalize the existing United States leadership in the emerging global "Virtual Coral Reef Ecosystem Monitoring Laboratory," and (3) provide for a solid scientific basis for future monitoring and assessment products/capabilities.

ENVIRONMENTAL DATA CENTERS

National Climatic Data Center (NCDC)

NCDC has the principal responsibility to manage the national climatological data program, including data and information services. To meet this responsibility, NCDC:

- Performs all data management functions regarding retrospective meteorological data, including data from *in situ* and remote sensing sources (satellites, radars, etc.). These functions include acquisition, archiving, retrieval, indexing, quality assessment, evaluation, synthesis, dissemination, and publication of data collected by global and national observation networks or systems. Meteorological data that have enduring value to the Nation and are sufficient to describe the climate are included.
- Designs and implements new systems, as necessary, for ingesting, processing, quality control and archiving of new data streams from the NWS modernization program.
- Operates as a designated Agency Records Center for processing, storage, and servicing of retrospective meteorological data records.
- Prepares and provides special products and services to users, as required, as a basis for regulatory standards and policy decisions.
- Maintains national and global databases for analyses of long-term climate trends and for monitoring global change.
- Provides facilities, data processing support, data exchange, and expertise, as required, to meet United States commitments to foreign nations, international organizations, and to the World Meteorological Organization's (WMO) programs.
- Operates the World Data Center-A (WDC-A) for Meteorology under the auspices of the International Council of Scientific Unions. In this capacity, NCDC archives the data collected by internationally sponsored research programs and actively exchanges climate data with foreign countries.

NCDC is the archive for meteorological data sets from World Climate Research Program and WMO World

Climate Data and Monitoring Program projects, such as the Tropical Ocean-Global Atmosphere (TOGA) Program, the Global Precipitation Climatology Program (GPCP), the International Satellite Cloud Climatology Program (ISCCP), etc.

National Oceanographic Data Center

The National Oceanographic Data Center (NODC) supports climatic services and research through its data management and data services activities. NODC provides data management for major climate-related studies, such as the TOGA program, the World Ocean Circulation Experiment (WOCE), and the Joint Global Ocean Flux Study (JGOFS). NODC also provides data products and services individually to researchers as well as to members of the operational marine community, e.g., the Navy, Coast Guard, and shipping industry.

NODC distributes on CD-ROM the Atlas of Surface Marine Data, which includes global surface marine observations, taken from Comprehensive Ocean-Atmosphere Data Set (COADS) files. It also includes objectively gridded fields of surface marine fluxes of heat, momentum, and fresh water. NODC also archives and distributes on CD-ROM surface marine data collected by NOAA's Coastal - Marine Automated Network (C-MAN) stations, and NOAA moored buoys. Both products are described on NODC web pages, and made available through the NOAA National Data Centers' (NNDC) Online Store.

National Geophysical Data Center

The National Geophysical Data Center (NGDC) manages geophysical data and information resources for NOAA and the scientific community. NGDC participates in a number of national and international programs that collect and provide data for research in meteorology, climatology, and space weather. NGDC operates the secretariat for the Scientific Committee for Solar-Terrestrial Physics and the World Data Centers for Solar-Terrestrial Physics, Paleoclimatology, Marine Geology and Geophysics, Solid Earth Geophysics, and Snow and Ice under the auspices of the International Council for Science.

NGDC is responsible for several meteorological and space weather databases. Space weather data on DMSP, GOES and POES satellites and all scientific data collected on DMSP satellites are officially archived by the Solar-Terrestrial Physics Division. NOAA's Paleoclimatology Program which manages geophysical data used to derive paleoclimate data and information is operated by the Paleoclimatology Group. Cryospheric data from ground-based and satellite instruments are managed by the National Snow and Ice Center which is affiliated with NGDC.

WorldWide Web (WWW) technology in the 21st Century poses new challenges and opportunities for NGDC and NNDC. NGDC have taken advantage of WWW-based applications through improved data discovery, automated inventories, on-line catalogs, data display, and data delivery systems. As a result, the number of users has increased dramatically. Since most of the new users are less familiar with the data than the regular users, additional burdens are placed on the NGDC and the other NNDC's to assure that quality data is provided in a display that is easy to understand and in a format that is easy to use. At the same time, new applications are under development which increase the need for quality data; they are the mining of information from the data archives and the running of data-driven numerical models from remote locations.

Satellite and Computer Systems

NOAA's Defense Meteorological Satellite Program (DMSP) at NGDC prepares research quality data recorded by scientific instruments on DMSP operational satellites for retrospective analysis and the official archive. Data sets include visible, infrared and microwave imagery, microwave soundings and *in situ* measurements of the space environment. The official archive is used to prepare data products, derive geophysical parameters including atmospheric and ionospheric principal components, and provide user services. New user services are provided through the Space Physics Interactive Data Resource (*www.ngdc.noaa.gov/dmsp*).

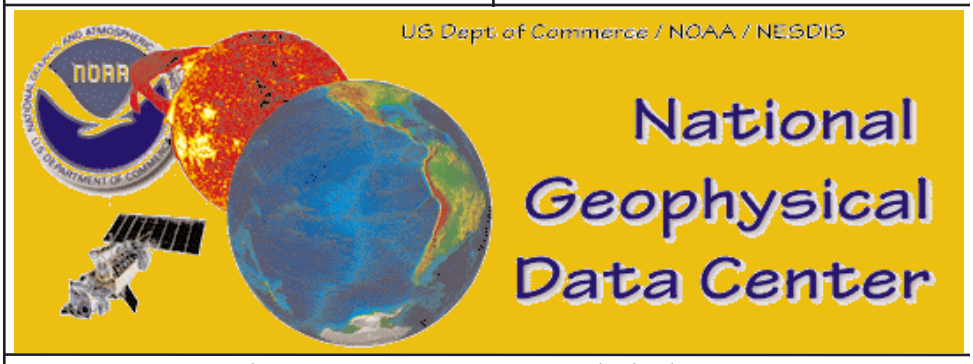

Figure 3-DOC-8. NGDC's web site banner.

NOAA's paleoclimate program to assemble global information on paleoclimate is operated by NGDC. The program has acquired many paleoclimate databases derived from geophysical data, namely tree-rings, pollen and macrofossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources. Paleoclimate databases can be displayed, searched, and retrieved using custom software (*www.ngdc.noaa.gov/paleo)*.

The Space Weather program at NGDC, also known as Solar-Terrestrial Physics (STP), prepares research quality data of the near-Earth

space environment for retrospective analysis and the official archive. GOES, DMSP, and POES satellites carry instruments that monitor the space environment; for example, the SEM instruments on GOES and POES and the SSIES, SSJ/4 and SSM instruments on DMSP. Future instruments, namely the GOES Solar X-Ray Imager, the GEOSTORMS measurements of particles and fields, and the DMSP Ultraviolet Imagers will greatly increase both the use and volume of space sensor data. Other data sets in the space weather archives includes measurements of solar activity, solar flares, magnetic activity, magnetic storms, ionospheric parameters, and ionospheric storms collected by NOAA and other agencies. The STP program has a long and successful history of cooperating with NASA, USGS, DOD, academia and other NOAA components.

The STP program at NGDC archives measurements of total solar and solar spectral irradiance for use in climate studies. The data sets are recorded on NOAA and NASA satellites and irradiance values inferred from ground-based solar imagery (*www.ngdc.noaa.gov/stp/stp.html).*

The National Snow and Ice Center (NSIDC) at the University of Colorado is associated with NGDC and maintains several cryospheric-related data sets of interest to meteorology and climatology. These data sets include a collection of historical photographs of glaciers, temperature, pressure and position data from drifting buoys placed on the central Arctic pack ice, and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing projects. NSIDC provides data management services for a variety of cryospheric research programs sponsored by NASA and NSF. In addition, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites. NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available at *www.colorado.edu/nsidc/nsidc.html.*

SUPPORTING RESEARCH

Climatology

NOAA's paleoclimate program to cooperate in research projects to use the combined global paleoclimate database for climate model verification and climate change studies is operated by NGDC. Objectives of the program are to cooperate with researchers and to conduct original research to describe the global patterns of annual-to-millennial scale climate change, to understand the causes of climate change, to separate man-induced climate change from natural variability, and to validate the models that are used to predict future climates. Support is received from the NOAA Climate and Global Change Program. More information is available at the NGDC website (*www.ngdc.noaa.gov/paleo/paleo.html).*

Remote Sensing

Operational meteorological satellite imagery provide a unique opportunity to monitor wildfires and population dynamics on global and nightly bases. NOAA's DMSP program at NGDC uses the nighttime imagery to locate sources of visible and infrared emissions including city lights, lightning, fires, flaring gas, and boats. City lights can be used to infer population density, economic vitality, and carbon dioxide emissions. Transient lights were used to locate and track the disastrous wildfires in Borneo in 1997 and the Amazon Basin in 1998 where ground-based and airborne measurements are inadequate at best and impossible at worst. More information is available at the NGDC website (*www.ngdc.noaa.gov/stp/stp.html).*

Wildfires Monitored from Space

Operational meteorological satellite systems offer a unique opportunity to monitor wildfires because each satellite records infrared emissions covering the entire globe each day. Instruments designed to detect clouds also "see" fires, many of which burn in very remote areas. NGDC has developed a unique technique to capture nighttime emissions from both large and small wildfires. The system has been used to assist firefighters in Indonesia, Mexico, Middle America and Amazonia. More information is available at the NGDC website (*www.ngdc.noaa.gov/dmsp/globalfires).*

Space Weather

The Space Weather program at NGDC conducts original research in space physics with an emphasis on space weather applications. Research focused on numerical modeling of the ionosphere and magnetosphere is conducted with resident and visiting scientists from the United States and other countries. Research projects use the extensive integrated databases archived at NGDC. In addition to building better models and improving our understanding of ionospheric and magnetospheric plasma processes, the research leads to improved data sets and new data products. More information is available at the NGDC web site w*ww.ngdc.noaa.gov/stp/stp.html.*

ENVIRONMENTAL RESEARCH LABORATORIES

Programs within the Environmental Research Laboratories (ERL) support various NOAA meteorological, oceanographic, and space science missions. The activities of ERL laboratories are oriented toward providing the scientific and engineering understanding, tools, and techniques that form the basis of improved national weather and climate services (Figure 3-DOC-9).

Within ERL, special emphasis is placed on improving severe weather and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. The key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall (HaL)" focus of the United States Weather Research Program (USWRP). They include more accurate prediction of track, intensity, surface winds, rainfall, and human impacts. In pursuit of improved utilization and dissemination of data, ERL laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector.

Observing Technology. Two ERL laboratories in Boulder, Colorado, and on in Norman, Oklahoma, are heavily involved with developing new environmental observing system technologies. The Environmental Technology Laboratory (ETL) develops and evaluates new environmental remote-sensing concepts and systems. This development and the associated environmental research directly supports the Nation's forecasting and warning services. A comprehensive view of the laboratory and its research can be found on the Web (*www.etl.noaa.gov*). The Forecast Systems Laboratory (FSL) (*www.fsl.noaa.gov*) takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The National Severe Storms Laboratory (NSSL) (*www.nssl.noaa.gov*) located in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS.

A major example of these activities is the development of the world's first major wind profiler network. An outgrowth of ETL basic research, FSL now operates a network of 30 unattended wind profiling Doppler radars that provide high resolution winds and temperatures aloft to National Weather Service (NWS) forecasters and modelers, universities, government researchers, and the private sector. The NOAA Profiler Network (NPN) has made significant contributions to improved forecasts and warnings since its completion in 1992.

In a continued collaboration between ETL and FSL, three NOAA profilers were recently installed in Alaska to support NWS volcanic plume tracking and hazard mitigation. All three profilers transmit at the new operational frequency of 449 MHz. The engineering requirements for the transition of wind profilers from an experimental frequency allocation of 404.37 MHz came from a collaborative effort between FSL, ETL, and the United States Air Force.

In another example of technology transfer, FSL and ETL are collaborating with several universities, NOAA's National Geodetic Service, and the United States Coast Guard to develop and deploy a network of surface-based water vapor observing systems for NOAA that utilize the Department of Defense's Global Positioning System (GPS). Some of these systems are installed at NPN sites. ETL and FSL will continue investigating the use of GPS receivers (surface and space-based) to achieve real-time, continuous observations of atmospheric water vapor for weather forecasting, climate monitoring, and satellite data calibration and validation.

FSL is investigating the use of super-pressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the

Figure 3-DOC-9. NOAA's Ronald H. Brown research vessel, university aircraft, and Tropical Atmosphere Ocean (TAO) array buoy.

balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, light-weight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle and the instrument package was successfully recovered after descent by parachute. In FY 1999, a 60-foot diameter super-pressure balloon will be tested with an instrument payload.

During FY 1999, ETL and FSL will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. One effort involves the development and testing of a new technique to combine wind profiler and radio acoustic sounding system (RASS) data to measure humidity profiles through the planetary boundary layer at profiler sites (Figure 3–DOC–10). Other efforts include developing tools and techniques to integrate the data from surface-based and satellite borne profiling systems for more effective use of these data in forecasts.

Figure 3-DOC-10. ETL Radio acoustic sounding system.

In a new development, ETL has demonstrated that tornadoes can be detected well before touch down by listening for their unique infrasonic signatures. Infrasonic antennas located in the central United States have been used to detect and locate numerous tornadoes. Verification has been provided by Doppler radar and visual sightings. This research effort is continuing and it is proposed that a network of these inexpensive infrasonic systems be deployed at WSR-88D sites to enhance early detection capability.

ETL will also continue development of Lidars and infrared Doppler multi-frequency radars as research tools to improve our knowledge of atmospheric winds, turbulence, and moisture processes. Development of dual-polarization Doppler and multi-frequency radars and passive radiometers will also be undertaken to study convective storms and their precursors, including in-cloud and entrainment processes. ETL will also continue research in the area of ocean remote sensing, including theoretical and experimental studies of rough surface scattering processes.

The discussion of observing technologies would be incomplete without mention of the North American Atmospheric Observing System (NAOS) Program. The overriding purpose of NAOS is to make recommendations on the configuration of the upper air observing system over North America and adjacent water areas. Government organizations and universities in Canada, Mexico, and the United States support NAOS. About 15 agencies from these countries have representatives on the NAOS Council, which identifies issues, sets priorities, coordinates the work of the program, and seeks financial support.

Eventually, the council will advise governments how to: (1) improve the utility of existing observing systems and reduce costs, (2) design a cost-effective observing system for the 21st Century, and (3) evolve toward that system from the present one. ERL representatives serve on the NAOS council and its two principal working groups.

The NSSL, known for its role in the development of the WSR-88D NEXRAD radar, continues to improve the software algorithms used by the NWS forecasters. NSSL is also exploring ways to enhance the WSR–88D hardware using dual polarization techniques. This is the first step in preparing the WSR-88D fleet for eventual implementation.

Tropical Atmospheric Research. The Tropical Dynamics and Climate Program of the Aeronomy Laboratory (AL) is using a network of remote-sensing wind profilers in a long-term study of tropical circulation and its impact on global climate. The Trans-Pacific Profiler Network consists of an array of wind profilers and Integrated Sounding Systems that make continuous measurements of atmospheric winds and other parameters in the tropical Pacific. In addition to 50 MHz wind profilers, the network is incorporating 915 MHz lower tropospheric wind profilers recently developed at AL. The observations, which extend from the boundary layer to the lower stratosphere, reveal the relationship between atmospheric vertical motions and convective systems in the tropics. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. The network will: (1) provide valuable improvements to the boundary layer and convective parameterization schemes used in general circulation models and (2) contribute to climate forecasting by furthering the understanding of the coupled ocean-atmosphere dynamics that governs the El Niño-Southern Oscillation (ENSO) phenomenon, the dominant component of interannual climate change.

Routine wind observations are made at Christmas Island using a 50 MHz

and 915 MHz profiler. Lower tropospheric wind measurements using 915 MHz profilers are made at San Cristobal, Ecuador, and Tarawa, Kiribati. In addition, surface and upper air measurements are being made at Nauru and Manus Island, Papua, New Guinea, both now operated by the DOE, using Integrated Sounding Systems installed by AL. Recently, a shipboard wind profiler has been brought into operation to provide measurements throughout the equatorial Pacific as the ship tends to buoys in the Tropical Atmospheric Ocean (TAO) array. An additional profiler was installed on the R/V Ron Brown to gather data during the Pan American Climate Studies (PACS) field program in the eastern tropical Pacific in August 1997 and will again do so in 1999. Data from these systems are used by NCEP and the European Center for Medium Range Weather Forecasting in their operational analysis and forecast products. The data are also used by climate researchers to support investigations of the variability of tropical atmospheric circulation systems.

Severe Weather Analysis and Forecasting Research. The NSSL in Norman, Oklahoma, focuses on research to understand and forecast severe weather systems and their associated hazards, such as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instrumented aircraft, and lightning-location networks. In addition, work includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, including research and development, for the WSR-88D program. In FY 1999, NSSL will continue to develop techniques in cooperation with the NWS to forecast and warn of weather hazards to aviation and the general public. Work with the resultant data from the 1994-1995 VORTEX experiment is leading to new understanding of severe thunderstorms and the tornadoes that they spawn, to improved ways to model and predict these storms, and to new generation algorithms for severe storm detection. Immediate technology transfer will be effected by close association with the WFOs, such as those in Norman, Oklahoma; Phoenix, Arizona; Melbourne, Florida; Pittsburgh, Pennsylvania; Cleveland, Ohio; Jackson, Mississippi; Minneapolis, Minnesota; Fort Worth, Texas; Denver, Colorado; and Salt Lake City, Utah.

In addition, NSSL is continuing to work closely with the NWS WSR-88D Operational Support Facility to re-host the Radar Product Generator, the Radar Data Acquisition system, and also the Principle User Position to an open system platform. The re-hosting will continue for the next several years and will result in improved capabilities for the WSR-88D. The new system will ease the incorporation of new applications, speed technology transfer, allow for incorporation of new hardware technology, and increase the portability of the software.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. FSL develops and evaluates prototype workstations for forecast office environments. Specifically, FSL has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. By maintaining state-of-the-art capability for use in research and development of operational techniques, it continues to provide a mechanism to evaluate weather service requirements for AWIPS.

FSL will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Communications, Addressing, and Reporting System (ACARS), WSR-88D Doppler radars, the NOAA Profiler Network, and weather satellites, especially GOES, are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more fully exploited in the Local Analysis and Prediction System which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. These efforts contribute toward the NWS modernization and restructuring.

ERL will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and NSSL is participating directly in training programs, such as the COMET in Boulder and the WSR-88D Operational Support Facility in Norman.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ETL and NSSL, the NWS Seattle WFO, NCAR, and the University of Washington. Support for the program is also being provided by the Office of Naval Research (ONR) and NSF. This research improves understanding of the effects of prominent terrain on West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds,

precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in FY 1994 and 1996, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. The results are providing information on how to improve forecasts of Northwest weather.

Taking advantage of the 1997-98 El Niño event, ETL led the California Land-Falling Jets Experiment (CALJET) with participation by PMEL, FSL, the Naval Research Laboratory (NRL), and the Naval Post Graduate School. CALJET took place between December 1997 and February 1998 and was designed to study the development of the pre-frontal low-level jet along the coast of California. This moist jet can cause severe, flooding rains along and near the coast as it impinges on the coastal mountains. The large volume of data gathered during this experiment, including those data from the NOAA P3 and from an array of radar wind profilers along the coast, will be analyzed throughout FY 1998 and FY 1999 to determine the mechanisms of jet development. This knowledge will be used with numerical models to improve the accuracy and lead time of forecasts of heavy, flooding coastal rains in California. This study is occurring with close cooperation between the scientists and the NWS forecasters in California.

Mesometeorology and Precipitation Forecasting and Warning Research. NSSL develops techniques to improve short-term forecasts of significant weather events. Through detailed case studies and regional climatologies, scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storms complexes. Studies underway include the precipitation structure of mesoscale convective systems, the interactions between mesoconvective systems and the larger environment, the use of satellites to infer storm development and rainfall, and winter storm forecasting procedures. In FY 1999, NSSL will continue to use polarization information to improve radar estimates of rainfall that will be the key to improving short-term flash flood forecasts.

In addition, NSSL is working with the NWS Storm Prediction Center (SPC) to improve SPC abilities to provide winter weather guidance. NSSL and SPC provided experimental forecasts of winter weather events to improve our understanding and refine our ability to provide severe winter weather guidance products. In FY 1999, NSSL will continue to support the SPC by providing improved methods for winter weather and flash flood forecasting.

Midlatitude Mesoscale Meteorology Research. At the Aeronomy Laboratory, the Atmospheric Dynamics Program combines observational and theoretical studies of mesoscale, high frequency atmospheric processes, focusing on internal gravity waves and vertical air motion. By improving the understanding of these dynamical processes, the research contributes to improvements in weather forecasting and the transfer of advanced meteorological measurement technology to operational use. Data for the studies is obtained from the 50 and 915 MHz wind-profiler radars at the Flatland Meteorological Observatory. The observatory makes continuous horizontal and vertical wind measurements in the very flat terrain near Champaign-Urbana, Illinois. The observatory also includes a 915 MHz RASS to measure temperature, an array of 24 digital barometers spread over Illinois, and standard surface and balloon-borne instruments. The research has shown that all enhancements of gravity-wave energy are associated with meteorological events, such as fronts, convection, or jet streams, and that such events always cause enhancements. In 1995, a multiyear program was initiated to study the dynamics of the atmospheric boundary layer, including measurements of the vertical entrainment velocity, which is of great importance to the vertical transport of trace species into the free atmosphere.

Hurricane Analysis and Prediction Research. The Hurricane Research Division (HRD) of the Atlantic Oceanographic and Meteorological Laboratory (AOML) explores hurricanes in dedicated research flights aboard the WP-3D aircraft operated by NOAA's Aircraft Operations Center (AOC). The P-3s carry a suite of instruments to measure a wide-range of meteorological quantities, including standard flight-level data, precipitation characteristics, remotely-sensed surface winds, vertical soundings, ocean thermal structure, radar reflectivity, and Doppler radar winds. In addition to the airborne observations, HRD develops techniques for real-time analysis and display of hurricane data, especially of surface winds. It also carries out modeling and theoretical studies closely tied to the observational program and studies interannual and interdecadal changes in hurricane activity.

The 1995-1998 hurricane seasons were the four most active consecutive ones in the >100-year quantitative climatology. There is a growing body of evidence indicating that the relatively low level of hurricane activity experienced in the 1970s and the 1980s is

over and that the first decade or two of the 21st Century will see a return to the more active conditions that characterized the 1940-1960s. If this hypothesis is true, land-use and development decisions made over the last two decades may be inappropriate to the present hurricane climatology and the need for improved forecasting and informed policy guidance will become pressing.

An exciting new tool for this effort is AOC's newly commissioned Gulfstream IV (G-IV) jet which successfully operated in the hurricane environment for the first time during the 1997 and 1998 seasons. The G-IV extends the envelope of observations throughout the depth of the troposphere. Use of these aircraft presents an unprecedented opportunity for better understanding and forecasting of hurricanes through detailed observations. Of special interest are the hurricanes' inner core, the oceanographic and upper tropospheric synoptic-scale forcings that control intensity and motion, and the kinematics and thermodynamics of the near-surface boundary layer. The GPS-based dropsondes procured as the G-IV's main scientific payload have a vital role in these investigations because of their high vertical resolution and superior thermodynamic and wind sensing capability.

The 1998 season constituted the first major field program for HaL carried out in collaboration with NASA's Third Convection and Moisture Experiment (CAMEX-3). Its success was unprecedented. NOAA and NASA aircraft flew a total of 66 scientific sorties in hurricanes Alex, Bonnie, Danielle, Earl, Hermine, Georges, and Mitch. Participation by the G-IV and NASA's DC-8 and ER-2 provided extensive *in situ* observations above the middle troposphere for the first time since the 1960s. In addition to airborne measurements, university teams with instrumented towers, mobile Doppler radars, and portable profilers coordinated with HRD to intercept hurricanes Bonnie, Earl, and Georges as they passed onshore. Current plans are to repeat this campaign in conjunction with CAMEX-4 in 2001.

The motivation for acquisition of the G-IV was a statistically rigorous demonstration, based upon more than a decade of experiments with the P-3s, that intensive observations of the flows surrounding hurricanes can produce dramatic (16-30 percent) reductions in track forecast errors. Data from multiple-aircraft experiments involving the G-IV and both WP-3Ds should confirm the GI-V's ability to improve forecasts. An intriguing possibility is adaptive targeting of aircraft observations to regions where they will do the most good.

The forecast system currently has limited skill in prediction of intensity. Though continuing research with the expanded aircraft fleet, the Nation can realize large (tens of billions of dollars per year) economic benefits through more accurate routine operational track forecasts. A second, equally significant, outcome is the promise of dynamically-based, skillful intensity forecasts. Because hurricanes inflict huge costs on the United States economy, even incremental improvements in forecasts have large benefit to expenditure ratios.

In addition to HRD research activities, the ERL scientists carry out hurricane research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. GFDL's Hurricane Dynamics group performs hurricane modeling research to study the genesis, development, and decay of tropical storms using multi-nested three-dimensional computer models of the hurricane system and its surrounding environment.

In the early 1990's, this research model proved so successful for simulation of observed storm behavior that the NWS adopted a version of it for use in operational forecasting. During the extraordinarily active 1995 and 1996 seasons, the GFDL model provided the most reliable hurricane-track forecast guidance available and contributed substantially to the dramatic error reduction in official forecasts that has occurred since its introduction.

Numerical Analysis and Prediction Modeling. As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved NWP models. Three groups at GFDL are engaged in weather research activities: Experimental Prediction, Mesoscale Dynamics, and Hurricane Dynamics (described above).

Experimental Prediction at GFDL develops and improves numerical models of the atmosphere-ocean-land system in order to produce useful weather forecasts with lead-times ranging from weeks to seasons and beyond. The group is pursuing several avenues of research to achieve such improvements. First, GFDL scientists are investigating methods of stochastic dynamic prediction in order to extract as much forecast information as possible from numerical prediction models, given imperfectly observed initial conditions. In addition, laboratory scientists are developing methods for the assimilation of ocean observations into prediction models in order to improve the forecast of the atmosphere and the ocean.

Mesoscale Dynamics at GFDL develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. The FSL implemented a Rapid Update Cycle (RUC) at NCEP in 1994. The RUC

gave a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in February 1998. This new version operates at 40-km horizontal resolution with 40 vertical levels and provides updates every hour, thus, incorporating information from virtually all high frequency data sources: hourly wind profiles, WSR-88D (Doppler radar) velocity azimuth displays, ACARS reports (up to 40,000 per day), cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites, and surface observations.

The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface. In FY 1999, with the arrival of a larger computer at NCEP, the way is open for expanding the geographical domain of the RUC and moving toward finer resolution of the computational grid (20 km).

Along with NCAR, NCEP, and a few universities, FSL is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal of this development, from the beginning, is that the WRF model should become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry.

Air Quality Research. The Air Resources Laboratory (ARL) carries out research on processes that affect the quality of the atmosphere, primarily in the context of air pollution deposition and emergency preparedness. Much of this work is in collaboration with other agencies, such as DOE and DOD. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media - aquatic, terrestrial, and biospheric.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Carolina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the Environmental Protection Agency on air pollution control strategies for attainment and maintenance of ambient air quality standards. The Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models. The Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The Special Operations and Research Division, in Las Vegas, Nevada, conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities.

ARL operates two national networks that focus research on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-run Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. This work forms an intersection with the new flux measurement networks in the United States and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing areal air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

ARL also provides forecast support to NOAA's emergency response systems with emphasis on nuclear and volcanic events. For this application, ARL develops and couples advanced mesoscale models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. Users also may access these products through the Internet.

The Aeronomy Laboratory (AL) conducts research on air quality as part of its tropospheric chemistry program. A primary focus is on understanding the processes of near-surface ozone formation in rural regions. Field experiments, laboratory work, and numerical modeling studies assess the relative roles of natural hydrocarbons emitted from vegetation, anthropogenic hydrocarbons, and nitrogen oxides in controlling ozone production. A series of field experiments have been conducted in recent years in the southeastern United States, a heavily vegetated region which frequently experiences elevated levels of ozone. Since 1994, these field studies have expanded to include measurements from an aircraft platform, the NOAA WP-3D, in addition to ground-based observations. In certain areas, analysis of the data has linked ozone production most strongly to anthropogenic nitrogen oxides and natural, but not man-made, hydrocarbons. It has also underscored the regional nature of the ozone formation process and suggested that some municipalities are affected by events beyond their control. These results have implications for the efforts of states to develop strategies to improve air quality in the region.

Ozone production on the global scale is being studied by AL in the North Atlantic Regional Experiment. The study has been undertaken in response to the growing realization that long-range transport of "greenhouse" ozone may influence atmospheric composition and climate on an interhemispheric scale. Comprehensive chemical and dynamical measurements, made from both ground-based and from airborne platforms during several field missions of this experiment, track the changing composition of air masses containing pollutants from eastern North America as these air masses are carried into the North Atlantic. Results indicate that the quantity of ozone generated photochemically from anthropogenic emissions on the North American continent exceeds that injected from the stratosphere. This conclusion supports the contention that ozone derived from anthropogenic pollution has a hemisphere-wide effect at northern temperate latitudes.

ETL uses its suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments as well as in complex orography.

Space Environment Services. NOAA and the Air Force jointly operate the National Space Weather Operations group in NOAA's Space Environment Center (SEC) in Boulder, Colorado. The SEC, working closely with the Air Force's 55th Space Weather Squadron (55 SWXS), provides forecasts, alerts, indices, and summaries of disturbances occurring on the Sun, in space, in the geomagnetic environment, and in the upper atmosphere. The services are used by DOD, DOT, DOC, DOI, DOE, NASA, NSF, commercial users, and the research community:

- To optimize the operation of technical systems that are adversely affected by disturbances in the space environment.
- To carry out research in the solar-terrestrial environment.

Examples of the adverse effects include loss or reduced efficiency of communication systems, radiation hazards to personnel and systems in high altitude aircraft and in space, degradation of surveillance and monitoring systems for defense, errors in navigation systems, perturbations of satellite orbits, and disruptions in power distribution networks.

SEC serves as the international World Warning Agency for the solar-terrestrial environment. It collects international data–solar-wind, X ray, sunspot, corona, magnetic, etc.--in real-time and from these data provides International URSIgram and World Days Service and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use. There is also a substantial and rapidly growing customer base in the private sector.

SEC operates with observations received from agencies that contribute their data and, in return, receive the synthesized and integrated services to meet their needs. Agencies making major contributions of data include: DOD, NASA, DOC, NSF, DOE, and DOI. SEC cooperates directly with NESDIS to receive solar X-ray, particle, *in situ* magnetic field, and plasma data from the SEM on GOES and the polar-orbiting NOAA satellites. Data are collected, stored, and displayed for analysis and products and distributed to outside customers primarily via the Internet (*www.sec.noaa.gov*), by NOAA Weather Wire, and digital data links (primarily operated by other agencies). Radio broadcast, mail, and recorded telephone messages are available to users as well.

Over the past year, SEC has instituted a large number of new capabilities and products which represent a major leap forward in space weather services. New, real-time solar-wind data are allowing SEC to extend the warning time for several geomagnetic storms from 0 minutes (Nowcast) to up to 1 hour in advance. SEC's Rapid Prototyping Center (RPC) has flourished under a Cooperative Research and Development Agreement

(CRADA) partnership. In March, 1998, SEC also initiated test products from the Magnetospheric Specification Model (MSM) - the first numerical model being transitioned into operations through the developing RPC mechanism. With its initial infrastructure and concept of operations developed through a CRADA partnership, the RPC is planned to grow into the primary mechanism for transitioning National Space Weather Program sponsored models into operations. In addition to these technical advancements, users will also benefit from 24 hour a day forecaster staffing implemented in October 1998.

Military. The United States Air Force operates the 55 SWXS in Colorado Springs, Colorado, to provide space weather support to DOD assets. The 55 SWXS operates and maintains the solar observing network with sites at Palehua, Hawaii; Learmouth, Australia; San Vito, Italy; Ramey, Puerto Rico; Sagamore Hill, Massachusetts; and Holloman AFB, New Mexico. The 55 SWXS shares space weather support responsibilities with its civilian counterpart the SEC.

Voluntary Observing Ship (VOS) Program. OAR operates a global VOS program that provides real-time meteorological and oceanographic data from selected vessels. Data are collected with the Shipboard Environmental Data Acquisition System, which transmits the information to NOAA via the GOES system. The information is then disseminated nationally and internationally using existing data networks. Presently, there are over 120 vessels in the program which record and transmit surface meteorological information four times per day at synoptic hours. Of these vessels, about 60 vessels are also equipped to collect expendable bathythermograph data.

Southern Hemisphere Drifting Buoy Program. In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, OGP, AOML, and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere. The buoys measure sea level atmospheric pressure, air temperature, and sea water temperature. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites.

Tropical Atmosphere Ocean (TAO) Moored Array. OAR is a partner with OGP in the implementation of the TAO moored-buoy array. TAO is a basin-wide array of moored ATLAS buoys deployed in the tropical Pacific that report surface wind, air temperature, sea surface temperature, 10 subsurface temperatures to a maximum depth of 500 meters, and 2 subsurface pressures in real-time via the ARGOS system. There are 69 buoys deployed. The array is operated by the TAO Project Office located at PMEL in Seattle, Washington, which has responsibility for management of project operations and logistics. While the principal objective is to support research objectives, the real-time availability of data makes it extremely valuable to operational meteorological centers (*www.pmel.noaa.gov/toga~tao/home.html*).

The Global Drifter Program. The Atlantic Oceanographic and Meteorological Laboratory, in Miami, Florida, manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700. Using research ships, Volunteer Observation Ships (VOS), and United States Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

NOAA Ship RONALD H. BROWN. NOAA recently installed and deployed a 5-cm Doppler precipitation radar to conduct studies of atmospheric processes over the ocean. The system has been shown to not only be effective for studying convective processes but also processes associated with marine stratus clouds. In late 1999, NOAA will install a next-generation shipboard wind profiler on the RONALD H. BROWN that is presently in development at the ETL. This profiler will be electronically stabilized (as opposed to the mechanically stabilized systems used on board ships to date) and will employ some new clutter-screen techniques to reduce interferences and obtain profiles much closer to the surface than have been possible to date.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to support effective management, promoting a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the federal government responsible for the health and safety of our Nation's coastal and oceanic environment. NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program. These programs provide a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. NOS, also, provides coastal oceanographic and meteorological products required by the NWS to meet its short-term weather and forecasting responsibilities including tsunami and storm surge warnings/forecasts.

National Water Level Observation Network (NWLON). NOS manages the NWLON, 189 stations located along the coasts of the United States and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other federal programs with data and supporting information, such as the NOAA Tide and Tidal Current Prediction program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program.

An event triggered NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS when the water level exceeds a specified high/low limit or when the rate of change between the standard 6-minute water level values exceeds a specified value.

The NOS Continuous Real-Time Monitoring System (CORMS), now operational, was designed to operate on a 24 hour/7 days a week basis to ensure the accuracy of tide and current observations acquired via the National Water Level and Physical Oceanographic Real-Time System (PORTS) Programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications. CORMS ingests real-time data from all field sensors, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data.

Physical Oceanographic Real-Time System. PORTS is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g., winds and visibility, needed by the mariner to navigate safely.

PORTS systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. The largest of NOS' existing PORTS installations is comprised of over 26 separate instruments. The smallest consists of a single water level gage and associated meteorological instruments, i.e. winds, barometric pressure, etc. These smaller PORTS installations are referred to as "PORTS Lite." Full systems are presently installed in Tampa, New York, San Francisco, and Houston/Galveston. PORTS Lite systems are presently installed at Tacoma, Washington, and the Chesapeake Bay.

Regardless of its size, each PORTS installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting United States ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of

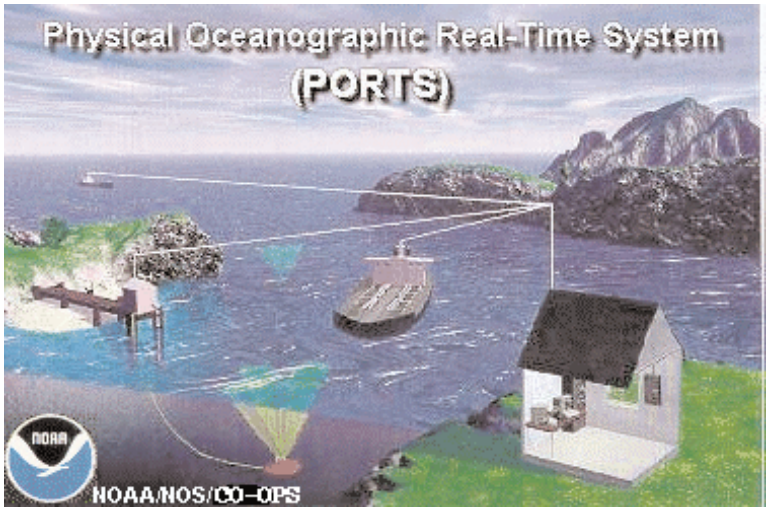

Figure 3-DOC-11. PORTS supports safe and cost-efficient navigation by providing ship masters and pilots with accurate real-time information required to avoid groundings and collisions.

dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS provides information to make navigation safer, thus, reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur.

In late 1997, NOAA signed a Cooperative Research and Development Agreement (CRADA) with the Ocean, Radar and Sensor Systems Division of the Lockheed Martin Corporation (LM). The purpose of this CRADA is to collaborate on the research and development needed to commercialize NOAA's PORTS technology. An extensible PORTS can be integrated with other marine transportation technologies, such as Electronic Chart Display Information Systems and Vessel Traffic Systems. Also, new developments will enable PORTS to incorporate biological and chemical sensor systems and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management.

The integration of PORTS technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available. The Chesapeake Area Forecasting Experiment (CAFE) is an NOS project that provides forecasts of total water level within the Chesapeake Bay in addition to the astronomical tidal prediction. Using wind observations from multiple locations to help force the model, the 1-year rms-difference between the modeled and observed water level at Baltimore is 9.4 cm.

Ocean Systems Test and Evaluation Program. The goal of the planned Ocean Systems Test and Evaluation Program (OSTEP) in Norfolk, Virginia, is to provide oceanographic and marine meteorological data quality assurance for NOS observations and derived products and services. The four objectives of OSTEP are: (1) evaluation of new technology for use in measurement systems, (2) integration and testing of field measurement systems, (3) development, test, and evaluation to determine measurement system readiness for operational deployment, and (4) life cycle evaluation of system performance, operations, and maintenance. NOS will provide the capability through a partnership with the Naval Surface Warfare Center/Carderock Division, the National Institute of Standards and Technology (NIST), commercial partners, and the Cooperative Institute for Coastal Physical Oceanography located at Old Dominion University.

AIRCRAFT OPERATIONS CENTER

The Aircraft Operations Center (AOC) provides aircraft support to many NOAA missions, several of them associated with the Natural Disaster Response Initiative (NDRI). In particular, AOC operates a fleet of aircraft to support NOAA's research and development programs to improve weather, marine, and climate services. It provides hurricane reconnaissance and surveillance support to NOAA's National Hurricane/Tropical Prediction Center with its Lockheed WP-3D and Gulfstream IV (G-IV) aircraft (Figure3-DOC-11) as well as flight services to other federal agencies and international programs approved by NOAA's Aircraft Allocation Council (NAAC). AOC's light aircraft provide aerial photography for nautical and aeronautical charting and living marine resources surveys.

AOC was established in October 1983 through a consolidation of all existing NOAA organizations and elements operating NOAA aircraft. This consolidation was accomplished to achieve a more efficient, more economical and safer operation of NOAA aircraft. Fourteen aircraft, located throughout the United States, are managed by AOC from its home base at MacDill AFB in Tampa, Florida.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, are supported by two WP-3D Lockheed Orion aircraft which carry a full array of state-of-the-art environmental research instrumentation. The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. AOC develops and calibrates specialized instruments, integrates user-supplied instrumentation into its automated dated recording systems, and processes and analyzes data sets collected during various field programs.

AOC recently integrated into its operation a new, high-altitude jet, the G-IV, which is used for hurricane surveillance. This aircraft flies in the environment surrounding hurricanes at altitudes up to 45,000 feet. The G-IV dispenses the new GPS dropwindsonde and transmits the resulting profiles of thermodynamic and wind information to the NCEP and the NHC for inclusion in their computer prediction models. Initial estimates of the improvement in hurricane track predictions for the two hurricane seasons to date is between 20 and 30 percent, and these improvements are expected to result in future savings of $10 million or more per hurricane in warning and preparedness costs. With its high-altitude capability, the G-IV is the central focus for additional research leading to improvements in hurricane intensity forecasts. With the addition of instrument pods and the installation of additional instrumentation this year, the aircraft will also be used for air chemistry studies and other research in the upper troposphere.

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provide storm data to the NHC in near real time, transmitting flight level data, dropwindsonde messages, and radar images via its aircraft-satellite data link. The AOC aircraft have primary reconnaissance responsibility for tropical storms and hurricanes in foreign airspace and also augment Air Force Reserve (AFRES) aircraft reconnaissance during particularly active storm periods when tasking requirements exceed available resources.

Land-falling hurricanes, a major subject of the USWRP and NDRI, receive particular attention from AOC aircraft. During the 1998 hurricane season, the G-IV and the WP-3D aircraft flew a combined total of over 400 surveillance, reconnaissance, and research hours on Atlantic storms that made or nearly made landfall in the continental United States. Joining with the AFRES and NASA aircraft, the three NOAA planes participated in the first multi-agency hurricane research experiment since Stormfury, a hurricane modification project that took place in the early to mid-70's. The Convection and Moisture Experiment III (CAMEX-3) experiment focused on the measurement of cloud moisture using a variety of space-borne and aircraft mounted remote sensors. The NOAA WP-3D's, with their *in situ* measurements, doppler radar observations, and cloud particle sampling will provide the much-needed "ground-truth" for this ambitious effort.

Figure 3-DOC-11. NOAA's Gulfstream IV (G-IV) will conduct high altitude research.